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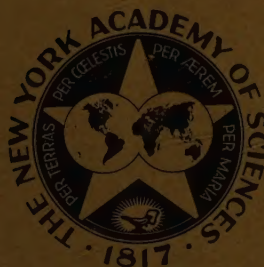
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PSYCHOPHYSIOLOGICAL REACTIONS TO NOVEL STIMULI:
MEASUREMENT, ADAPTATION, AND RELATIONSHIP
OF PSYCHOLOGICAL AND PHYSIOLOGICAL
VARIABLES IN THE NORMAL HUMAN

By

ROSCOE A. DYKMAN, WILLIAM G. REESE,
CHARLES R. GALBRECHT, PEGGY J. THOMASSON



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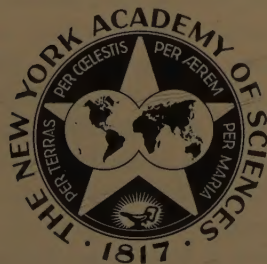
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INTRODUCTION

The literature contains many reports of psychophysiological studies designed to clarify relationships between intraorganismic and extraorganismic factors operating in the intact organism. The probable importance of such investigations is matched by the complexity of design, the technical methods employed, and the interpretation of the results. In most research of this nature an investigator's capacity to integrate his data is exceeded by the variety of variables to be considered.

Many investigators, some of whom will be mentioned, have shown considerable finesse and sophistication in approaching psychophysiological problems, but none of them would claim complete satisfaction with the methods currently at hand. In this paper we have not solved to our own satisfaction any of the basic methodological problems that hamper such investigations. Our hope is that we have highlighted some of the problems and suggested some worthwhile approaches for future investigation.

We are engaged in psychophysiological studies of animals and humans. A variety of human populations is being studied: medical students, recruits of the United States Marine Corps, and psychiatric and neurological patients. This report is restricted to our studies on medical students. Specifically, this first report explores: (1) various methods of autonomic quantification, the Lacey²⁶ method in particular; (2) a variety of autonomic reactions to novel stimuli of moderate intensity; and (3) relationships between autonomic variables and selected psychological variables. In order that the present work may be seen in proper perspective, we shall begin with a review of past studies concerning autonomic reactions to novel stimuli and autonomic quantification.

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Reactions to Novel Stimuli

The studies in this area encompass 2 types of reactions, the orienting response (OR) and the startle reflex. Investigators of these reactions have not usually been concerned with each others' work. While these reactions shade into each other, they appear to be clearly different at their extremes. In a normal subject, whether animal or human; a weak stimulus produces an OR and a strong stimulus a startle reflex. It appears from observations in our laboratory that an auditory stimulus of moderate intensity often produces a mild startle reflex followed by orienting behavior. The startle reflex is a brief, nondirected movement (tightening of all musculature), often completed within a period of 0.5 seconds;²⁸ the OR appears to have a longer latency (although this has not been systematically studied), a much longer duration and, in addition, its pattern of movement is directed toward the stimulus that elicits it.³⁶

The startle reflex has received more attention over the years^{4, 24, 28, 30, 31, 40, 50} than the OR,^{6, 7, 30, 31, 36} and this review will be concerned primarily with the OR. We feel that the OR is an important segment of behavior worthy of intensive investigation. Along with the startle reflex, the OR probably ties in with the larger problems of arousal and attention.

The OR is most easily seen in the lower animals. Any mild or moderate novel stimulus causes an animal to direct or orient the appropriate receptors into a favorable position for receiving that stimulus. This reaction, termed the motor component of the OR, has undoubtedly been seen by every person familiar with animal behavior. In 1910, Pavlov³³ described this motor reaction to novel stimuli and called it the orienting or focusing reflex. His major concern at that time was how to control the response, since it interfered with the conditional response. Pavlov constructed the sound-shielded camera in an effort to remove extraneous stimuli that are invariably present in the conditioning laboratory: changes in the intensity of illumination of the room, sounds produced by the experimenters and recording apparatus, a sudden gust of air, and a speck of plaster falling from the ceiling. During the next few years Pavlov came to see that the OR was an important aspect of behavior in itself and, in 1916, he characterized it as the investigatory reflex and discussed inquisitiveness as an elaboration of this response.

The response has survival value for the organism, but on occasion it can also be the undoing of man and beast. Hunters stop a rabbit from running by whistling or shooting near the animal; the rabbit loses its life as the result of a response that does not serve an adaptive purpose in these circumstances. The potential danger to man is perhaps less

than in the lower animals, because the nervous system of man contains greatly elaborated inhibitory mechanisms.

In 1947 Robinson and Gantt³⁶ reported that the OR in dogs consist of specific changes in heart rate (HR), respiration (R) and salivation, in addition to the above-described motor response. Of the changes studied by Robinson and Gantt, the cardiac were the most consistent and the most easily evaluated.

Whitehorn has theorized that the response consists of two phases, (1) an alerting reaction (autonomic arousal), followed by (2) a questioning reaction (motor reaction).^{*} No systematic investigation of these two phases has yet been made, but such studies may be possible with appropriate instrumentation and experimental design. It would appear from all the above considerations that the OR is a gross reaction of the organism consisting of at least motor, autonomic, and subjective components.

There have been a number of studies indicating that the OR is of significance for neurology. In the above-mentioned study by Robinson and Gantt,³⁶ the response was present in two dogs from which most of the cerebral cortex had been removed, and the response appeared to be identical, as judged by motor and cardiac components, to that in normal animals. Gantt¹² concluded that the OR is primarily a subcortical reflex, and he suggested that the persistence of a strong OR after the elaboration of the conditional response is an indication of weakened cortical activity or predominance of subcortical excitation.

It has been reported that alcohol and amobarbital sodium have similar effects on the OR.^{12,48} Under both agents the OR persisted long after the conditional responses had disappeared, even when an animal was so lethargic that it could no longer take food. By contrast, Gliedman and Gantt¹⁵ found that chlorpromazine and reserpine completely eliminated the motor and cardiac components of the OR in the dog while having only moderate effects on motor conditional responses and little or no effect on autonomic conditional responses.

In agreement with the work of Robinson and Gantt, Reese *et al.*^{34, 35} found the OR present in psychotics with demonstrable structural changes in the brain. It did appear, however, that the autonomic and motor components of the OR were lesser in magnitude for patients than for normal subjects. Although they studied gross motor movements of the hands, tremors of the hands, HR, R, and skin resistance (SR) changes, the only evidence of orienting behavior occurred in SR changes and hand movements.

From the evidence now available it would appear that there are species differences in the speed of adaptation to auditory stimuli; this

^{*}This conception of the OR was originated by John C. Whitehorn of the Phipps Psychiatry Clinic, Johns Hopkins Hospital, Baltimore, Md.

is true for both intra- and intersession gradients of responses. In the typical dog, adaptation or "extinction" of the OR requires a rather prolonged exposure to the signals that are used to produce it; for example, 10 to 15 mild auditory signals per day for a period of 2 or 3 weeks.^{7, 36} Within a daily session there is a decrement in response, the first few trials each day producing responses of a relatively greater magnitude than the last trials of the same day. In addition, the first few stimuli of a given day seem to produce larger responses than the last few stimuli of the previous day. Preliminary observations indicate that the intra- and intersession decrements are much shorter in the human. The intersession decrement of the OR suggests a rudimentary type of learning.

There are studies pertaining to the psychological implications of the OR that should also be mentioned. Fleck,¹⁰ in studying dogs, stated that the OR seems to be more dependent upon the emotional state of the animal than the intensity of stimulation. In another paper, the same investigator reviews the literature on the OR,¹¹ presenting laboratory and case material relating the OR to extreme vigilance and even to panic behavior as it appears in mental patients. In somewhat parallel fashion Kubie^{24, 25} considered anxiety as a continuous startle. Actually, panic would seem more related to startle, and anxiety to continuous vigilance. Welch^{43, 44} reported that anxious patients give a smaller SR response to auditory stimuli than normal subjects.

There have been a number of investigations of psychophysiological reactions that were not designated as related to either the OR or the startle reflex. Syz⁴⁰ studied the SR and R responses of schizophrenics to emotion-laden words, an automobile horn, pinpricks, and the threat of a pinprick. He found that the autonomic reactions of his patients differed from those of normals in many ways, including the resting levels of activity, the number of delayed responses, and the frequency of spontaneous bursts of activity unrelated to external stimuli. Davis *et al*⁴ studied 9 psychophysiological variables in response to intense auditory stimuli. They reported that the SR response, interpulse interval, and volume pulse adapted with repetitions of the stimulus. Systolic blood pressure, pressure pulse, respiratory rate, finger volume,* and the latency of the SR response gave no evidence of adaptation, but breathing amplitude actually increased on the successive trials. The effect of auditory stimulus intensities of 70, 90, and 120 db. was also studied, and it was found that the magnitude of autonomic response in a number of systems was proportional to intensity. Most autonomic variables were affected in a parallel way by changes in intensity.

*Finger volume refers to changes in the size of the finger resulting from the distribution of blood. They are recorded by a plethysmograph or a volume recorder. This device records the changes in the size of the finger as the arterioles constrict or dilate.

In all of the "normal" human studies the adaptation to novel stimuli occurred rapidly, that is, within 5 to 10 trials. It appears, furthermore, that the adaptation in most systems is approximately parallel. In a previous conditioning study by Dykman *et al.*⁶ involving 3 tones, each reinforced by an electrical stimulus of graded intensity, it was found that motor differentiation is approximately parallel to cardiac differentiation, but this is not always the case.^{13, 14} We suggest that a lack of integration of the components of the OR is indicative of psychopathology, and this is one of the hypotheses underlying our studies. We also hypothesize that the adaptation or extinction rate of patients will differ from normals.^{43, 44}

In summary, we believe that there is much to be learned about psychophysiological adaptations to novel stimuli, and that these are relevant to human adjustment. Many of the studies mentioned have employed inadequate scaling methods, and the findings are in need of verification. The differentiation of the startle and orienting reactions is an important endeavor in itself. Many studies designated as one or the other have involved, as does the present one, some mixture of these two basic reactions. It would appear that both the startle and orienting responses are mediated by subcortical mechanisms, but that adaptation is largely a cortical phenomenon. It also seems likely that the immediate arousal state of the subject influences the magnitude of both the OR and the startle reflex.

The Problem of Quantification

Questionable procedures of scaling are a major stumbling block in all psychophysiological research,^{38, 39} particularly in autonomic research. While instrumentation is sufficiently developed so that reliable autonomic measures may be obtained, the interpretation of these measures is another matter. It can not be said, for example, that an SR change of 5000 ohms at an initial resistance of 50,000 ohms is comparable to the same change at an initial resistance of 100,000 ohms; the mathematical increments do not correspond to the biological increments. A number of investigators have been concerned with this problem, and SR has received more consideration than the other autonomic variables.⁵⁰

Darrow¹ became concerned with this problem about 1932, and proposed that the SR response be measured as conductance rather than as resistance: as the difference between the reciprocal of the stimulus level and the reciprocal of the prestimulus level rather than as the absolute difference between the two levels. This measure was based upon the finding that changes in conductance are proportional to changes in perspiration. In a later paper, Darrow² suggested in view of the

psychophysiological "laws" that log conductance, which he defined as the difference between the logs of the prestimulus and stimulus conductance values, might be a better measure.

In 1936 Wenger and Irwin⁴⁵ studied the SR levels of both infants and adults under conditions of wakefulness and sleep, taking readings every 5 min. They obtained from each subject's readings the mean SR level and the standard deviation; the correlation between SR levels and standard deviations was 0.90. Whether a given subject showed a marked fluctuation in SR on waking, for example, was found to depend upon his SR level prior to waking. To solve the problem that this presented for scaling, the data were transformed into standard *z* scores.⁸ Haggard¹⁸ pointed out that this technique could not be used to make comparisons between subjects, since the standard measures were based on the distributions of the SR levels of a single subject.* Even more important is the fact that the technique of Wenger and Irwin⁴⁵ controlled for differences between subjects only when each subject tended to remain within some restricted SR subrange; for a single subject the regression of change on initial levels was not taken into account.

Haggard,¹⁸⁻²¹ in a series of papers published between 1945 and 1950, studied the limitations of various techniques in quantifying SR changes: resistance change measured in ohms, conductance change (Darrow), log resistance change, and log conductance change. Haggard's log conductance change differed from Darrow's in that he employed the log of the difference between prestimulus and stimulus conductance values. Of the measures he studied, log conductance was the best.

Haggard found that both the absolute mean SR response (in ohms) and the variability of the responses increased with increasing prestimulus levels; thus, the variability of the SR responses is related to the mean. In deriving this relationship, Haggard obtained the means and the variances of the SR responses at different prestimulus levels. When the data were transformed to log conductance units as defined by Haggard, the relative magnitude of the SR response was approximately constant throughout a rather extensive prestimulus range, and the successive variances at different prestimulus ranges remained approximately constant. It appeared that he had established a measure that could be legitimately employed in such statistical manipulations as analysis of variance and factorial design.

In 1957, Wilder⁴⁷ published a summary article of his work on the "law" of initial value. This work summarizes a number of his earlier papers, the first appearing in 1930. From 1930 on, Wilder studied the changes in a number of systems (such as blood pressure, blood sugar

*This is possibly untrue, since in the present work significant correlations were found between intraindividual and interindividual data (see RESULTS below).

level, and foot temperature) as produced by various pharmacological agents and stimulation (such as pilocarpine, adrenalin, acetylcholine, changes in room temperature, electroconvulsive shock, and cigarette smoking). In the case of agents stimulating the function under consideration there was a tendency toward heightened levels of functioning with low initial levels, but there was either minimal change or a paradoxical decrease at high initial levels. The autonomic changes produced by inhibitory agents were opposite to those produced by excitatory agents. Wilder seems to have been the first to recognize that autonomic responses other than SR are dependent on initial levels. Wilder's "law" may be related to the paradoxical and ultraparadoxical phases described by Pavlov³³ and is perhaps a general "law" of arousal. In the paradoxical phase of a conditional response strong conditional stimuli become less effective than weak stimuli and, in the ultraparadoxical phase, positive conditional stimuli are ineffective; negative conditional stimuli evoke the conditional response previously associated only with the positive stimulus.

Lacey,^{26, 27} in a series of studies beginning about 1950, verified Wilder's law in several autonomic systems. His studies involved a variety of stresses and populations. He very early became concerned with the problem of the mathematics to be used in quantifying autonomic responses and related Wilder's law to homeostasis, stating that "... any induced excitation or inhibition of an autonomically innervated structure instantly initiates a series of changes that serve to nullify the disturbance" (Lacey²⁶). Lacey suggested that any mathematical model that is used to quantify autonomic responses should be rooted in physiological theory, and he feels that the regression model satisfies this requirement: responses elicited at either high or low initial levels tend to regress toward the mean of the distribution of prestimulus levels. He believes that this method corrects for varying prestimulus levels and, at the same time, allows for cases where there is either no change in function or a decrease in function at high initial levels of autonomic activity. Lacey emphasized the fact that Wilder's law is not a statistical artifact resulting from the restricted range of response possible to an organism functioning at high initial levels, but rather that it is a phenomenon of physiological homeostasis resulting from increased feedback in the systems undergoing change.

Having demonstrated that autonomic responses are a function of prestimulus levels, Lacey points out that the traditional methods of scoring autonomic responses (that is, techniques involving percentage change or algebraic change) involve redundancy and spurious correlation. Redundancy enters because no more information is obtained from a group of individuals functioning at the same initial level by deriving responses

in terms of the initial level than in considering only response levels. A spurious correlation is involved for the reason that initial levels enter as a common factor in the variables that are correlated: responses are defined in terms of differences or ratios between initial and stimulus levels, and these are correlated with initial levels.

It may be seen from the above-mentioned studies that a number of investigators have been concerned with the problem of autonomic quantification. A variety of mathematical models has been employed, and the regression model as employed by Lacey seems to be the most satisfying from the standpoint of physiological considerations. A technique such as that of Lacey or Haggard is necessary in most autonomic studies because it is impossible to determine what constitutes an autonomic response, or compare responses in different systems for a single person, or compare the responses of one individual with another (both within and between systems) without a consideration of the correlation between stimulus and initial level of functioning. Furthermore, levels vary with age in even a relatively homogeneous population (see RESULTS below), and any technique that removes the dependence of stimulus levels on resting levels would at the same time tend to control the variation of these levels with age.

METHOD

Subjects. Forty male junior medical students between 22 and 33 years of age were chosen as subjects. Their participation in the experiment was required as a routine part of their course requirements in psychiatry. The subjects were selected on the basis of their scores on the Medical College Admission Test (MCAT) and the Taylor Manifest Anxiety Scale to ensure heterogeneity with respect to ability and emotionality (see *Psychophysiological Relationships* under RESULTS below, for a description of these tests). Specifically, the test results were ranked in 3 anxiety levels: low, middle, and high. For each anxiety level there were 3 MCAT levels: low, middle, and high. There were thus 9 groups in all, with 4 to 6 students in each group.

In an attempt to elicit a uniform attitude of uncertainty, the students were given no information concerning the purpose of the experiment in advance of their participation, and those who had served as subjects were asked not to discuss the procedures with other students. To our knowledge, there were no violations of this request, and this was checked by asking each new subject what he had heard about the experiment.

Procedure. On arriving at the laboratory, the student was instructed to wash his feet. This was to ensure a clean site for the SR electrodes. He was then led to the electrostatically shielded experimental chamber

and seated in a comfortable upholstered chair with his legs resting on an ottoman. The SR electrodes were fastened to the left leg, one on the inferior surface of the plantar arch and the other just superior to the internal malleolus. HR electrodes were attached to the wrists and the right leg. In most cases HR was recorded between the arms, but occasionally it was recorded between the left wrist and the right leg. A pneumograph was placed around the student's chest or abdomen at the level of maximum expansion, and a set of earphones was adjusted to a comfortable position on his head. After the apparatus was fastened, the student was left alone in the chamber and was observed through a one-way vision mirror from the adjacent recording room.

The student was then instructed over the speaker system to stay awake and to keep his head and eyes toward the front. A rest period of 15 min., of which the last 8 were recorded, followed the instructions. The rest period terminated with the presentation of a tone of 800 cps, 5-sec. duration, and about 60 db. This same tone was repeated once every minute for 18 min. through the bilateral earphones.* The last tone was followed by a series of alternating "nonemotional" and "emotional" questions presented at intervals of 1 min. The student was instructed to think about the questions, but not to answer them aloud. All signals (tones or questions) were given at the peak of expiration in an attempt to control the effect of R on HR. The questions were as follows: (1) How many seconds in a minute? (2) How do you feel about your studies? (3) How many minutes in an hour? (4) Has our test today upset you? (5) How many hours in a day? (6) Do you like the way you look? (7) How many days in a week? (8) Do your classmates like you? (9) How many months in a year? (10) When do you tell lies? (11) Did you answer the personality test falsely?

The last question refers to the Taylor scale.⁴¹ A 3-min. period of recording followed the last question. About 50 min. after entry, the student was removed from the experimental room and interviewed by one of us (CRG). The student was asked to dictate his impressions of the experiment and was then administered a standard questionnaire that surveyed his knowledge, attitudes, and feelings about the experiment and provided certain background information concerning him (see *Psychophysiological Relationships* under RESULTS below).

Apparatus. SR was recorded by a Fels dermohmmeter and an Esterline-Angus recorder. This ohmmeter is a constant-current device,

*This differs from the conventional OR procedure in that auditory stimuli are usually presented via loud speakers located a variable distance from the organism. Earphones were employed in the present study because we were attempting to develop a comfortable headset for the presentation of bilateral auditory and visual stimuli. It is recognized that the location of the sound source may be very important, since autonomic responses may depend upon the ease of localization.

and it provides a continuous record of SR from 0 to 500,000 ohms, utilizing 5 sensitivity scales. Each scale divides the total range of SR into a number of equal subranges, the more sensitive scales having the greater number of subranges. The 20,000-ohm scale was chosen as most convenient for our experiments; on this scale, any change in SR greater than $\pm 10,000$ ohms from the midpoint of the chart automatically shifts the ohmmeter to a new subrange. The total resistance and the change in resistance are known at all times and, particularly important, a deflection of 5,000 ohms produces the same deflection whatever the initial level. The ohmmeter receives its input signal from a series circuit containing the subject (contacted by 2 nonpolarized electrodes), a variable resistance, and an electronically regulated constant current of 70μ amp. Each electrode consists of a small plastic cup mounted on a zinc base. The cup is filled with paste made from zinc sulphate, bacto-agar, and water. The accuracy is ± 1 per cent for all resistance readings.

HR was recorded with a Fels cardiometer and an Edin galvanometer. The cardiometer integrates the interval between beats, providing a continuous tracing of HR in beats per min. The accuracy is ± 1 beat in the range of 40 to 120 beats per min. and ± 1.5 beats in the range of 60 to 180 beats per min. R was recorded with a pneumograph connected via a Statham strain gauge and Edin carrier preamplifier to an Edin galvanometer. Auditory signals were presented to the subjects over a set of Brush crystal earphones (Model 6). The earphones were enclosed in sponge-rubber cushions.

Basic measures. From each student's record the 2 following SR values (in ohms) were obtained: the SR level at the time a stimulus was presented (prestimulus level), and the SR level at the point of maximum deflection within a period of 20 sec. following the onset of a stimulus (stimulus level).

The stimulus and prestimulus periods for HR were the 5 sec. following and the 5 sec. preceding the onset of the stimuli. In each of these 2 intervals of time, the maximal HR in beats per min. was obtained (a conversion chart was used to correct for the slight lack of linearity of the cardiometer). The stimulus value for R was the mean duration of the 2 cycles following the onset of the stimuli, and the prestimulus value was the comparable mean duration preceding the stimuli.

It is to be recalled that recordings were made for a period of 8 min. preceding the first tone and for a period of 3 min. following the last question. At 1-min. spacings during these rest periods, arbitrary prestimulus intervals were laid off, from which SR, HR, and R readings comparable to those taken during stimulation were obtained.

RESULTS

In a paper of this length some difficulty would be encountered in a consideration of the experimental results apart from their interpretive significance; therefore most of the findings will be discussed as they are presented.

The statistical treatment of the data is divided into three parts: (1) a section concerning intraindividual analyses of subjects' responses in each of the autonomic systems described; (2) a section dealing with interindividual analyses of these responses; and (3) a section involving the relationships among autonomic responses and various psychological variables. While this procedure provides for a threefold classification of the experimental findings, it was necessary in some instances for the purpose of clarity to present data in a section other than that in which they would fall according to the schema.

The results of this paper are restricted to the autonomic components of the responses to tones and questions. Systematic studies of the gross motor component have not yet been made. The first tone (but rarely any other stimulus) elicited a variety of skeletomotor reactions: a mild startle reflex characterized chiefly by eye blinking,²⁸ a gradual shifting of the eyes upward, a "questioning" facial expression, and a tendency to sit up slowly in the chair. Some or all of these reactions may have been present in any one student. It was observed in pilot observations that the pattern of response was about the same whether the tones were presented from a distance or via earphones, except that in the case of distance stimulation some subjects turned their heads toward the source of the sound. The gross head-turning response in these subjects disappeared after the first stimulus.

The subjective responses of the students, verbalized in the post-test interview, indicated that the experiment was perceived as a mild stress. Some students were concerned that something embarrassing about them might be learned. A number of students said that during the early tones they felt as if the worst was yet to come. A few expressed concern that they might receive a painful stimulus such as an electric shock. When asked about the various disturbing features of the experiment, 8 of the 40 students rated physical constraint first, 6 rated highest the startling effect of the first tone, and 16 rated general uncertainty concerning the nature of the experiment as the most disturbing aspect. Twelve students thought the tones were disturbing or painful.

Intraindividual Analysis

A graph plotting stimulus levels of autonomic activity as a function of prestimulus levels of autonomic activity was constructed for each of

the 40 students (see basic measures under *Procedure* above). Each graph was a plot of an individual's reactions to the 18 tones and 11 questions. Three graphs—SR, HR, and R—were prepared for each student. The product moment coefficient of correlation (PMr), the standard error of estimate (SE), the slope, and the spread were obtained for each graph. Spread was measured as the difference between the highest and lowest readings obtained for tones and questions, regardless of whether these readings represented stimulus or prestimulus levels of autonomic functioning.

FIGURE 1 presents some of the better and poorer graphs in each of the 3 autonomic systems from the standpoint of the consistency of the data. The solid line in each figure represents (in the least-squares sense) the average stimulus levels for the successive prestimulus levels, and this is referred to as the regression of stimulus on prestimulus. In the event the slope of the regression line approaches zero, as in the HR graph on the right, the mean stimulus value becomes the reference point in the scaling procedure. All of the SR graphs gave good evidence of linearity, and the poorer SR graphs were at least equal to the best HR and R graphs in this respect.

Ten of the students had SR levels (both stimulus and prestimulus) to the tones that were appreciably different from their SR levels to the questions. The linearity of these students' graphs was striking, considering the fact that the subjects functioned over such a wide range of SR values. The graph in the upper left-hand corner of FIGURE 1 shows one of these subjects (note the separation of the levels to the tones and questions). The question arose as to how these "disparate" subjects compared with other "nondisparate" subjects with respect to slopes, SEs, and PMrs. For purposes of such comparisons, another group of 10 subjects was selected whose SR levels to the tones and the questions were not separated. These nondisparate subjects were matched with the disparate group on the basis of spread.

TABLE 1 presents certain statistical data on these 20 subjects. It can be seen that the group with disparate levels had the higher PMrs ($p = 0.05$ by binomial test) and slopes ($p = 0.17$ by binomial test).^{*} The PMrs and slopes for the disparate group are in part higher, because the extremes play a disproportionate role in weighting these 2 statistics. The SEs are less for the disparate group than for the nondisparate group ($p = 0.05$ by binomial test). This depends in part upon the fact that responses emitted at relatively low prestimulus levels tend to be less variable (see subsequent paragraph). It appears from a study of

^{*}The binomial probabilities given in this paper were derived from tables prepared by the National Bureau of Standards,⁹ except that when the number of items was greater than 49 the method of approximation from the normal curve was used.⁸

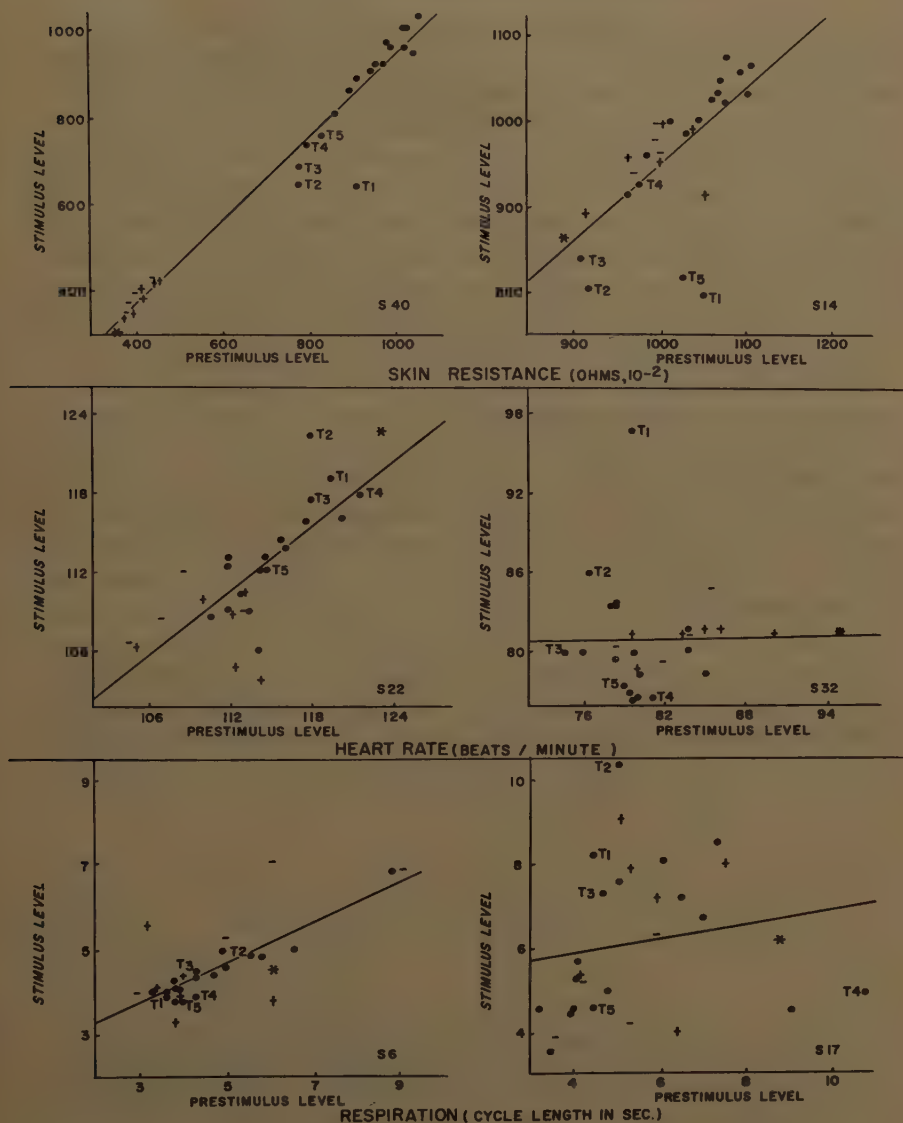


FIGURE 1. Samples of the intraindividual graphs that are better and poorer from the standpoints of consistency and linearity of regression. In each graph, the first 5 tones are numbered and the remaining tones appear as dots. The first question is starred, and the emotional questions are indicated with a plus sign and the nonemotional questions with a minus sign. The subject code number appears in the lower right-hand corner of each graph. The skin resistance values were coded by dividing by 100.

TABLE 1 that the disparate data are as adequately described by a linear relationship as are the nondisparate data. No specific statistical tests of linearity were made in this research since the individual graphs gave no evidence of a departure from linearity.

The separation of the plots for the tones and the questions was not nearly so clear in the case of HR and R as in SR, but there were 12 HR graphs and 10 R graphs in which the points for at least 8 questions were separated from all the remaining points. In 3 of the HR graphs and in 4 of the R graphs the separation was in stimulus and not prestimulus levels. The remaining disparate graphs in these 2 systems were similar to the SR graphs: if a separation occurred, it involved both the stimulus and prestimulus levels.

Several of the graphs in FIGURE 1 show a rapid adaptation (or extinction) of the response as evidenced by the deviations of the first few tones from the best fitting line (only the first 5 trials are numbered in this figure). For the successive prestimulus levels of each graph, the predicted stimulus level may be read from the regression line. Response magnitude is dependent upon the deviation of a stimulus reading from the predicted stimulus level. For purposes of scaling, the deviation is quantified by dividing it by the SE of the distribution. The repetitive application of this operation for each successive stimulus level of a single subject produces a population of *z* scores that are then transformed to *T* scores having a mean of 50 and a standard deviation of 10. The *T* scores are a linear transformation of the deviations from the

TABLE 1

COMPARISON OF SUBJECTS GIVING DISPARATE SR RESPONSES WITH
SUBJECTS NOT YIELDING DISPARATE SR RESPONSES
TO THE TONES AND QUESTIONS

Disparate subjects				Nondisparate subjects			
PMr	Slope	SE	Spread	PMr	Slope	SE	Spread
0.97	0.98	3,330	48,000	0.82	0.87	6,400	50,900
0.94	1.03	2,600	32,500	0.68	0.91	5,900	31,400
0.99	1.03	1,100	44,200	0.41	0.20	2,900	41,000
0.97	0.96	1,000	16,500	0.99	1.03	700	14,900
0.97	0.92	1,600	35,600	0.88	0.95	4,900	33,300
0.99	1.01	1,600	49,600	0.82	0.98	7,600	51,900
0.95	1.12	2,500	28,600	0.95	0.95	2,500	27,500
0.86	1.01	4,000	35,000	0.65	0.74	4,900	32,400
0.98	1.02	2,500	52,100	0.91	1.06	5,300	55,300
0.98	0.98	5,200	75,600	0.72	0.62	9,400	77,400

regression line. This is a technique frequently employed in the field of educational measurement.^{8,17}

This technique of quantification is an adaptation of a method proposed by Lacey,²⁶ but it differs from his method in that he uses the PMr between stimulus and prestimulus levels as the best-fitting linear relationship and the coefficient of nondetermination as a measure of variation. His procedure takes into account not only the relationship considered here (stimulus levels as a function of prestimulus levels), but the opposite relationship (prestimulus levels as a function of stimulus levels). The PMr is the geometric mean of the slope of these two functions.⁸

Our use of the specific regression of stimulus on prestimulus rather than the PMr rests upon the assumption that the prestimulus levels are a logical independent variable and constitute a relatively good indicator of the on-going level of arousal. Furthermore, the heterogeneity of the prestimulus levels markedly affects the correlation, but the regression is relatively independent of heterogeneity.¹⁷ It is to be recognized, however, that the prestimulus levels in a serial type of experimentation are dependent upon the previous stimuli and, from this point of view, may be considered as another aspect of response. If this is the case, there is no logical dependent variable; the 2 types of "responses" are associated with each other in some complex, unspecified manner, and the PMr is the more defensible statistic for scaling purposes.

FIGURE 2 presents frequency distributions for the PMrs, slopes, SEs, and spreads. In most individuals there is a significant correlation between stimulus and prestimulus levels in the three autonomic systems, which supports the law of initial values (see *Introduction*). It may be seen that the PMrs are higher on the average for SR than for HR or R, and this indicates that there is more variation not related to the specific stimuli in HR and R than in SR.

The SR stimulus levels of the subjects ranged from about 10,000 to 160,000 ohms. The corresponding HR levels varied between 57 and 135 beats per min., and the R mean cycle durations ranged from 1.4 to 27 sec. The median SEs in the 3 systems were approximately 3000 ohms in SR, 3.5 beats per min. in HR, and 0.6 sec. in R. The SE in SR is approximately 2 per cent of the total intersubject range. The comparable percentages for HR and R are 4 and 2 per cent, respectively. There were 3 subjects who held their breath at various times during the experiment. Two or 3 long cycles of 20- to 25-sec. duration in each of these subjects creates a considerable distortion in the statistics, for the typical cycle rarely lasts longer than 8.0 sec. The intersubject range in R would be reduced if breath holding were corrected by establishing, for example, some arbitrary time limit for an R cycle.

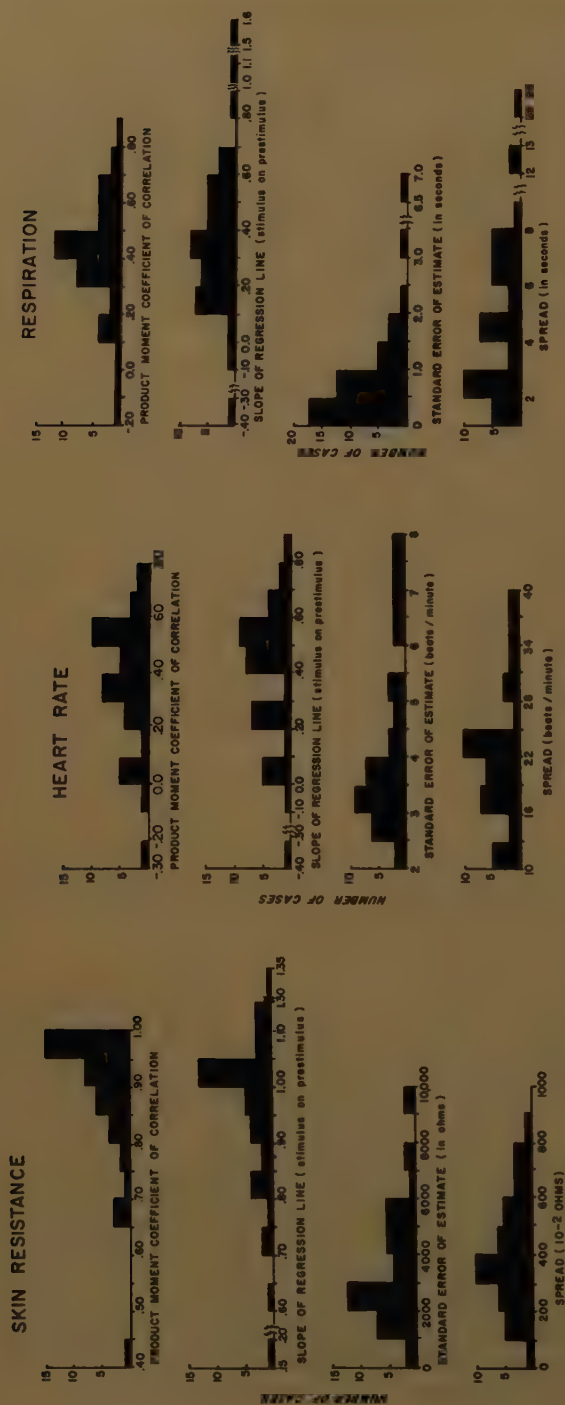


FIGURE 2. Intraindividual frequency distributions for product-moment coefficients of correlation, slopes, standard errors, and spread (see text).

R was recorded at a paper speed of 5 mm. per sec., and the accuracy of reading the records was about ± 0.1 sec. Since the SEs for R tend to cluster at values less than 1.0 sec., it would have been desirable to have employed a faster paper speed. In general, the R data were the least consistent and the most difficult to evaluate, and many evidences of this are encountered in the data of this paper. Much of the literature on R is based upon various types of qualitative variables, and these are possibly better than quantitative variables.

Several rank-order correlations were run between the various statistical variables of FIGURE 2, both within and between systems. The intraindividual slopes and PMrs were correlated 0.63 in SR, 0.83 in HR, and 0.73 in R. These coefficients are undoubtedly spuriously high, since common elements are involved in the variables that are correlated. There is sufficient variance not accounted for, however, to suggest that a scaling technique based on regression would differ from one based on the PMr. The subjects were more reactive in SR than in HR or R to the early tones as compared with the later tones, and it is possible that the lower rank-order correlation between slopes and PMrs in SR results from this relatively greater reactivity.

The spread was correlated with the SE 0.66 in SR, 0.84 in HR, and 0.84 in R (rank-order correlations). It is believed that only a negligible spurious element is involved in these correlations. The relatively high concordance of spread and SE might be expected, since both variables are different aspects of the same common factor, namely, variation. The high correlation in R is surprising in view of the disparate forms of the distributions for SEs and spreads in this system. It is difficult to account for the somewhat lower rank-order correlation in SR, but this may result from shifting levels (both stimulus and prestimulus) that attenuated rather than increased the SEs (TABLE 1). Marked shifts in levels of SR were consistently produced by the first tone and the instructions concerning the questions. While such shifts occurred in other systems, they were less dramatic and they more frequently involved a schism of stimulus and prestimulus levels.

The rank-order correlations of TABLE 2, which involve no spurious element, provide an estimate of the correspondence of the statistical variables in different systems. None of the coefficients in this table are statistically significant. Thus, an individual's reaction in a given autonomic system as indicated by the 4 statistical variables is not predictable from his response in another system. Other evidence of a lack of concordance between systems is presented below.

In many of the individual graphs there was evidence of a lack of correspondence between the manifest trend of the scatter plot and the trend reflected by the least-squares regression line, although there

TABLE 2

RANK-ORDER INTERCORRELATIONS BETWEEN INTRAINDIVIDUAL
STATISTICAL VARIABLES IN SKIN RESISTANCE (SR),
HEART RATE (HR), AND RESPIRATION (R)*

	HR PMr	R PMr
SR PMr	- 0.11	0.23
HR PMr	-	0.05
	HR slope	R slope
SR slope	- 0.11	0.06
HR slope	-	0.13
	HR SE	R SE
SR SE	- 0.04	0.11
HR SE	-	0.22
	HR spread	R spread
SR spread	0.08	0.26
HR spread	-	0.05

*Each coefficient in this table is based on 40 subjects.

was no evidence of a departure from linearity. Of the 40 graphs in each of the 3 autonomic systems, 27 of the SR, 16 of the HR, and 10 of the R graphs gave evidence of a discrepancy between the manifest trend of the data and the trend indicated by the mathematically fitted line. This type of discrepancy is illustrated by the SR and HR graphs of FIGURE 3. The inspection lines in this figure were drawn through the evident trends of the points, neglecting the points deviating markedly from the scatter plots. Such inspection lines tend to minimize the variance of the 2 regression lines (stimulus on prestimulus and the reverse relationship), approximating to some extent the correlational coefficient. This suggests that the correlational model is somewhat better for scaling purposes than the regression model; but, even though the PMr minimizes the variance of a scatter plot, it does not follow that the data are fitted well except in some arbitrary mathematical sense.

In the present work it was found that the early tones played a disproportionate role in affecting the regression line, the PMr, and the SE of the SR data. Simply eliminating the first tone from consideration and basing the regression line on the remaining 17 tones and 11 questions increased the SR slopes and the PMrs in 9 of 10 randomly selected students. The greatest increase occurred when the slopes or PMrs deviated markedly from 1.00. For example, omitting the first tone increased one student's SR slope from 0.20 to 0.85 and the PMr from 0.41

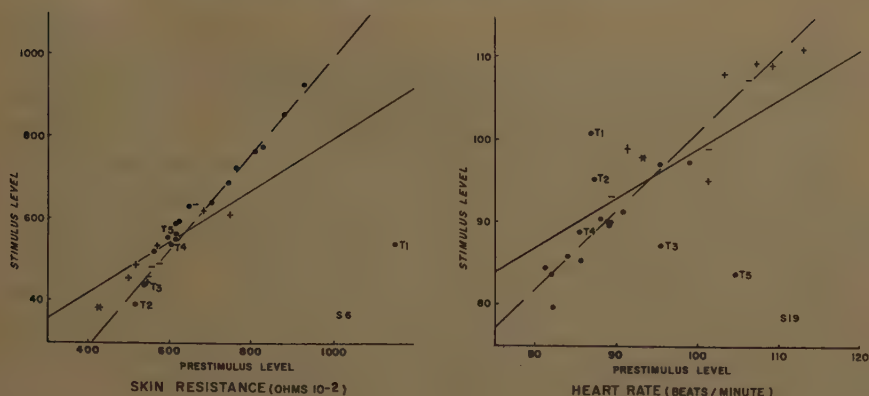


FIGURE 3. Skin resistance and heart rate graphs in which there is a lack of correspondence between the least-squares regression line and the manifest trend of the data. The solid lines were determined by the least-squares method and the dotted lines by inspection. The subject code number appears in the lower right-hand corner of each graph.

to 0.75, and another student's slope was increased from 0.62 to 1.07 and the PMr from 0.72 to 0.97. To consider a more typical example, one student's slope was increased from 0.95 to 1.01 and his PMr from 0.88 to 0.95. The SEs of all 10 subjects decreased.

A slope greater than 1.00 in SR indicates a smaller relative response at high prestimulus levels (that is, a higher level in ohms) than at low prestimulus levels. A slope of 1.00 indicates equal responses of some relatively constant magnitude at all prestimulus levels. Both types of slopes appear to be a violation of the "law" of initial values. There were only 4 subjects in the entire sample who had an SR slope greater than 1.10, but the number of SR slopes in the vicinity of 1.00 is very high (FIGURE 2). There were no slopes higher than 0.85 in HR, and the 3 slopes higher than 0.80 in R occurred in 3 individuals who held their breath.

There was a systematic tendency for the students' SR levels to adjust with trials. This was observed in the records as increasing and, in a few cases, as decreasing, stimulus and prestimulus levels to the successive tones and questions. The adjustment process was often superimposed on adaptation, and it outlasted adaptation (FIGURE 1). It is possible that the relatively higher slopes in SR than in HR or R depended upon an interaction of adaptation and adjustment. The SR responses were decreasing in magnitude at the same time the level of SR was increasing.

Inspection of the 40 SR graphs revealed 33 that gave evidence of

adjustment, but only 16 of the HR and 8 of the R graphs exhibited such adjustment. The evidence for systematic adjustment in HR and R was not good even in those students whose graphs indicated some type of adjustment. For several subjects, PMrs between stimulus levels and trials and prestimulus levels and trials were computed, and the correlations were frequently high in SR but generally low in HR and R. The multiple correlation in SR between stimulus levels and a combination of prestimulus levels and trials was approximately equal in some subjects to the PMr between stimulus and prestimulus levels and the PMr between prestimulus levels and trials. It is possible that some over-all improvement in scaling might be achieved by taking the combined effect of prestimulus levels and trials on stimulus levels into account. The significance of such a refinement is difficult to evaluate, since there is a very high correlation between stimulus and prestimulus levels of SR in some subjects, with neither level bearing any relationship to trials.

As mentioned earlier, the adjustment process was not continuous from the beginning of an experiment to the end. Many subjects exhibited shifts in their levels of autonomic functioning that were most frequently associated with the first tone and the instructions concerning the questions. This was particularly true of SR, in which there were often 2 adjustments, one occurring within the tone period and another within the question period. While such shifts were seen in HR and sometimes in R, they were rarely followed by adjustment (FIGURES 1, 3, and 14). Only a few subjects gave evidence of an uninterrupted adjustment in any of the 3 systems.

Much has been written concerning the normalization* of autonomic data.^{18-21,26,38,50} It was hoped that the T scores derived in this paper could be used in evaluating systems of maximal reactivity for the different subjects, and that they could be added across systems to obtain an accurate measure of total autonomic functioning. Evidence will be presented to show that these operations are not legitimate without some further transformation of the T scores.

In order that a given T score have an unambiguous interpretation in different distributions, it is necessary that the distributions be similar in form, whatever the form. Normality was not expected for the reason that the adaptation process per se would tend to produce skewness. Of the 40 intraindividual SR T-score distributions, 39 were positively skewed, 1 was negatively skewed, 25 were leptokurtic (peaked), and 2 were platykurtic (flat). Of the HR distributions, 22 were positively skewed, 11 negatively skewed, 7 normal, 4 leptokurtic, and

*Normalization refers to the process of transforming an obtained set of scores into the normal bell-shaped distribution.

9 platykurtic. Approximately 29 of the 40 respiratory distributions were positively skewed, 5 negatively skewed, 6 normal, 12 leptokurtic, and 10 platykurtic. * In general, the degree of kurtosis and skewness is greater for SR than for HR and R, and the most consistent evidence of a systematic adaptation was found in SR.

The question to be answered is whether the evident lack of correspondence of the distributions is sufficient to invalidate comparisons between and within subjects. For each subject, the low and high T scores for all responses in each system were tabulated in addition to the differences between the low and the high T scores (range). TABLE 3 shows central tendency and variability data for the low and high scores and for the range. The estimated semi-interquartile deviation (estimated Q) refers to Q estimated from the standard deviation by the well-known formula: $Q = 0.6754$ standard deviation. The standard deviations were calculated by $N-1$ formula.⁸

The results shown in TABLE 3 are surprising. All means and medians differ by less than one T-score unit. Q was less than 3 T-score units from the standard deviations in all systems. The estimated Q s obtained from the standard deviations differed by less than 2 T units from the obtained Q s. This suggests that the T scores within an autonomic system serve as a reliable measure of whether a subject is giving a response of greater magnitude to a given stimulus than another subject. The intercorrelations reported in TABLE 6 offer further support for this conclusion.

TABLE 3
CENTRAL TENDENCY AND VARIABILITY DATA FOR THE INTRA-
INDIVIDUAL LOW AND HIGH T SCORES, AND THE T-SCORE
RANGES IN SKIN RESISTANCE (SR), HEART RATE (HR),
AND RESPIRATION (R)

Statistics	SR scores			HR scores			R scores		
	Low	High	Range	Low	High	Range	Low	High	Range
Mean	38.01	83.65	45.64	29.94	72.38	42.44	32.69	76.58	43.89
Median	38.95	84.45	45.58	30.45	71.95	41.89	33.62	75.95	42.81
Standard deviation	3.27	7.23	6.00	5.32	5.45	4.89	5.54	6.51	6.83
Q	1.76	5.60	5.14	3.75	3.12	3.38	2.88	3.75	5.21
Estimated Q	2.21	4.88	4.05	3.59	3.68	3.30	3.74	4.39	4.61
$Q-Q$ estimated	-0.45	0.72	1.09	0.16	-0.56	0.08	-0.86	-0.64	0.60

*A skewed distribution is one in which the scores are not symmetrically placed with respect to the mean, so that there are low scores without corresponding high scores and vice versa. Kurtosis refers to the relative peakedness or flatness of a distribution; that is, the scores may pile up in the middle of the distribution, with few or no extreme scores, or the scores may be spread fairly evenly throughout the mid-low, middle, and mid-high ranges.

TABLE 4

CENTRAL TENDENCY AND VARIABILITY DATA FOR THE INTER-INDIVIDUAL LOW AND HIGH T SCORES, AND THE T-SCORE RANGES IN SKIN RESISTANCE (SR), HEART RATE (HR), AND RESPIRATION (R)

Statistics	SR scores			HR scores			R scores		
	Low	High	Range	Low	High	Range	Low	High	Range
Mean	36.78	81.66	44.88	24.18	73.54	49.37	29.77	88.48	58.71
Median	36.89	80.37	43.08	24.32	72.10	48.08	30.16	87.45	59.32
Standard deviation	2.21	6.90	6.64	5.83	5.59	6.32	4.47	9.15	8.12
Q	1.16	5.43	5.66	4.30	3.82	4.35	3.49	6.25	5.61
Estimated Q	1.49	4.66	4.48	3.93	3.77	4.26	3.02	6.17	5.48
Q-Q estimated	-0.33	0.77	1.18	0.37	0.05	0.09	0.47	0.08	0.13

TABLE 3 indicates, however, that comparisons across systems are not legitimate. The SR scores are appreciably different from the HR and R scores; for example, the highest and lowest mean SR scores are about 10 T units above the highest and lowest mean HR scores. These results might be expected from the fact that humans are simply more reactive in SR than in HR or R, at least in the present experiment. The greater comparability of the HR and R data may depend upon a lesser degree of reactivity found in these two systems.

TABLE 5

INTERINDIVIDUAL COEFFICIENTS OF CONCORDANCE AND RANK ORDER FOR VARIOUS BLOCKS OF STIMULI

Stimuli	Coefficients of concordance		
	SR	HR	R
Tones			
1-2	0.73*	0.27	0.53*
1-6	0.77*	0.21	0.33*
7-12	0.52*	0.28*	0.25†
13-18	0.46*	0.32*	0.26†
Questions			
2, 4, 6, 8, 10	0.47*	0.25	0.35*
3, 5, 7, 9	0.43*	0.36†	0.46*
1, 11	0.32†	0.10	0.40†

* $p < 0.01$

† $p > 0.05$

TABLE 6
RANK-ORDER INTERCORRELATIONS AMONG
ABSOLUTE AND INTRAINDIVIDUAL AND
INTERINDIVIDUAL T SCORES*

Scores	Skin resistance		Heart rate		Respiration	
	Inter.	Intra.	Inter.	Intra.	Inter.	Intra.
First tone						
Absolute	0.90	0.56	0.97	0.82	0.70	0.58
Intra.	0.61	—	0.78	—	0.59	—
Second tone						
Absolute	0.89	0.61	0.96	0.86	0.90	0.51
Intra.	0.58	—	0.67	—	0.59	—
First question						
Absolute	0.85	0.50	0.99	0.75	0.72	0.66
Intra.	0.45	—	0.77	—	0.76	—
Last question						
Absolute	0.84	0.63	1.00	0.46	0.79	0.68
Intra.	0.71	—	0.45	—	0.82	—

*All correlations are significant at the 1 per cent confidence level.

Thus, if our interest is that of determining the system in which a subject is relatively more reactive, it is necessary to transform the T scores into equivalent distributions. Either some positively skewed distribution could serve as the norm, or the scores could be normalized. It would appear that no single mathematical transformation (such as square root or log) would be satisfactory for the variety of distributions obtained.²⁶

The remaining intraindividual results are concerned with the adaptation process. In the regression method, adaptation is indicated by the successive stimulus levels gradually approaching some more-or-less constant deviation from the regression line (FIGURE 1). To show adaptation more clearly, graphs were constructed for each student, plotting his intraindividual T scores to the first 10 tones. Adaptation is then apparent in the leveling off of the T scores. On each T-score graph a best-fitting line for trials 5 through 10 was drawn by inspection and, if any of the first 3 responses deviated from this line by at least 10 T-score units (1 standard deviation) in either direction, adaptation was assumed to be present. The best-fitting line could be either higher or lower than a T score of 50.

It should be understood that no T score, however low, necessarily implies the absence of a response, and that a T score of 50 indicates an average response. Furthermore, a T score does not necessarily vary with the direction of change in an autonomic system. For example, a decrease in HR in the absolute sense yields a T score greater than 50 if the deceleration is less than the predicted deceleration for a given prestimulus level. However, a T score greater than 50 generally corresponds to a decrease in SR, to cardiac acceleration, and to an increased rate of breathing.

FIGURES 4, 5, and 6 present intraindividual adaptation curves of four subjects in the three autonomic systems studied. The curves on the left in each figure were derived from the T scores and those on the right from the absolute scores. An absolute score is the difference between the prestimulus and stimulus levels (prestimulus minus the stimulus level in SR and R, and stimulus minus prestimulus level for HR), and it neglects the regression of stimulus on prestimulus levels. The correlation between absolute scores and T scores will be reported later.

By the T-score procedure, 34 of the 40 subjects gave evidence of adaptation in SR, 24 of adaptation in HR, and 21 of adaptation in R. The comparable number of adapters in absolute scores was 36 in SR, 25 in HR, and 20 in R. The number of subjects adapting in both T scores and absolute scores was 34 for SR, 20 for HR, and 15 for R. When the results from the 2 types of scores failed to correspond in reflecting adaptation, the evidence for adaptation was not as good generally as when the 2 types of scores corresponded.

Inspection of the intraindividual curves of all subjects revealed that: (1) in general, the T-score curves were similar to the corresponding absolute curves; (2) adaptation in one system did not enable the prediction of adaptation in another; (3) T-score curves were somewhat better over-all than the absolute curves in reflecting a systematic adaptation process; (4) the typical response where there was good evidence of adaptation was a drop in SR and an acceleration in HR and the rate of breathing; and (5) of the three systems, SR was most consistent in exhibiting adaptation, HR was next, and R was the least consistent. Most of the foregoing conclusions are evident from FIGURES 4, 5, and 6.

A study of the T scores indicated that 35 subjects gave their first to fourth (inclusive) response of greatest magnitude in SR to the first tone. The comparable number of subjects who accelerated for HR and R was 20 and 12, respectively. No subject gave his first to fourth (inclusive) smallest SR reaction to the first tone, but there were 2 subjects who did so in HR and 6 subjects who did so in R. The expected

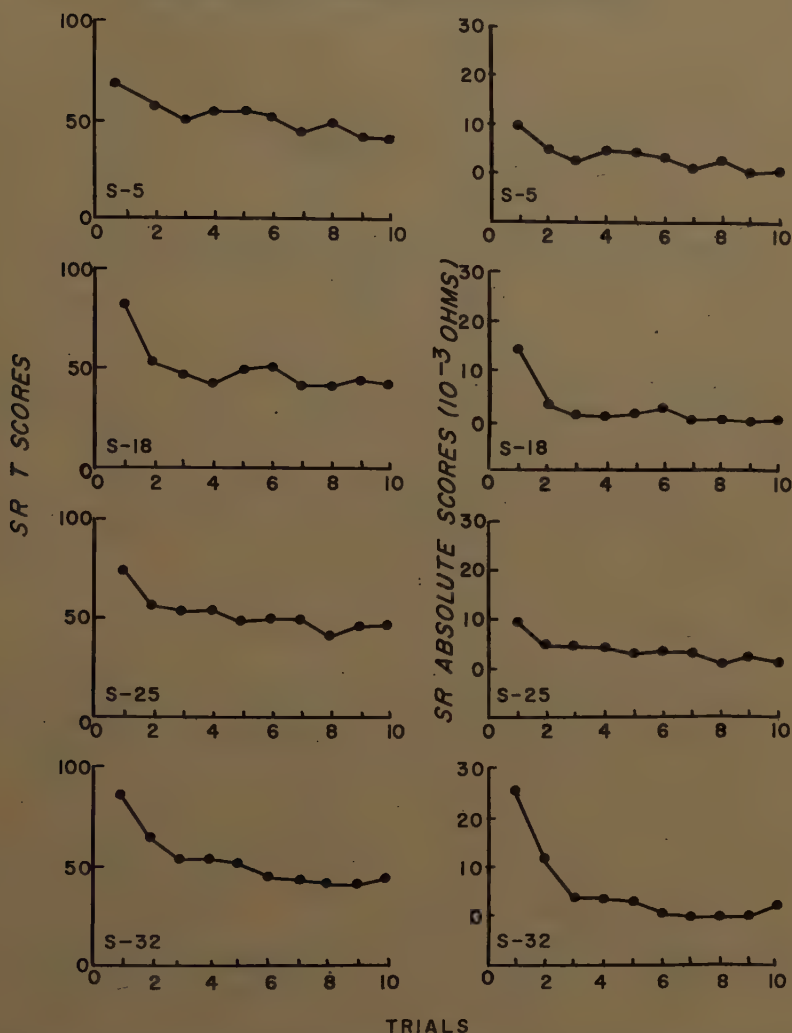


FIGURE 4. Intraindividual adaptation curves in skin resistance (SR) for T scores (graphs on the left) and for absolute scores (graphs on the right). The subject code number appears in the lower left-hand corner of each graph.

number of 40 subjects who would give their first to fourth largest or smallest response to any single stimulus by chance is 6.

FIGURE 7 presents the average T scores of the 40 subjects to the first 10 tones and indicates that the average subject required 3 trials for SR and HR adaptation. The evidence for a systematic adaptation in R was poor. The HR and R results are confounded in such averages by decelerators and accelerators and by subjects who did not respond.

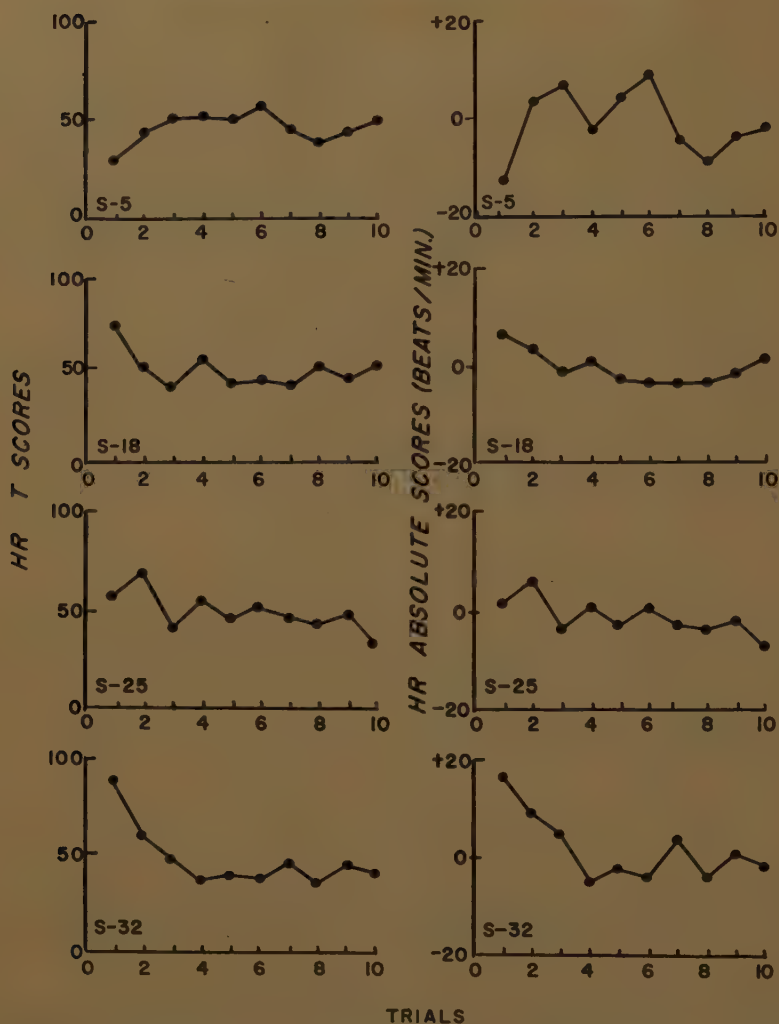


FIGURE 5. Intraindividual adaptation curves in heart rate (HR) for T scores (graphs on the left) and for absolute scores (graphs on the right). These are graphs for the same 4 subjects shown in FIGURE 4.

FIGURE 8 gives T-score data for cardiac accelerators and decelerators. The subjects were divided into 2 groups: those who accelerated on more than one half of the stimuli and those who decelerated on more than one half of the stimuli in terms of absolute units. The one subject having an equal number of trials in which he accelerated and decelerated was eliminated. The form of the adaptation curves is similar for the 2 groups, with a tendency for the decelerators to have higher

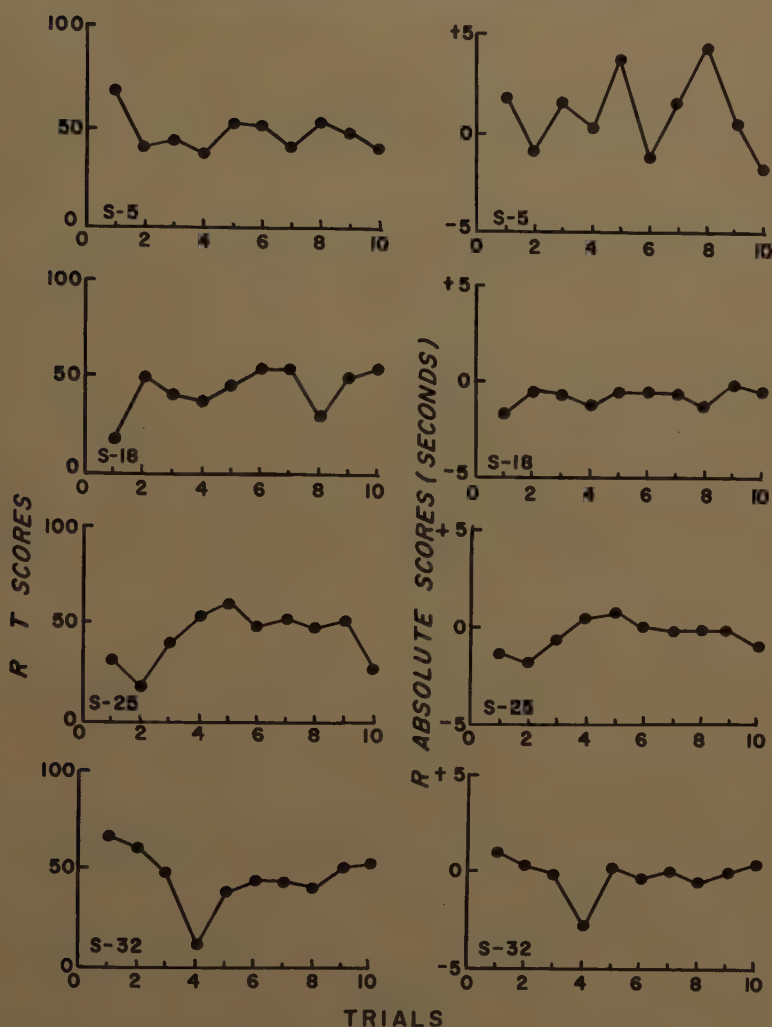


FIGURE 6. Intraindividual adaptation curves in respiration (R) for T scores (graphs on the left) and for absolute scores (graphs on the right). These are graphs for the same 4 subjects shown in FIGURES 4 and 5.

T scores to the early tones than the accelerators. The corresponding absolute curves, which are not presented, were similar in form to the T-score curves.

FIGURE 9 shows the number of subjects who had T scores greater than 50 on each of the first 10 tones. In 38 subjects, the SR response to the first tone was larger than the predicted response. The comparable number of subjects for HR and R was 34 and 27, respectively.

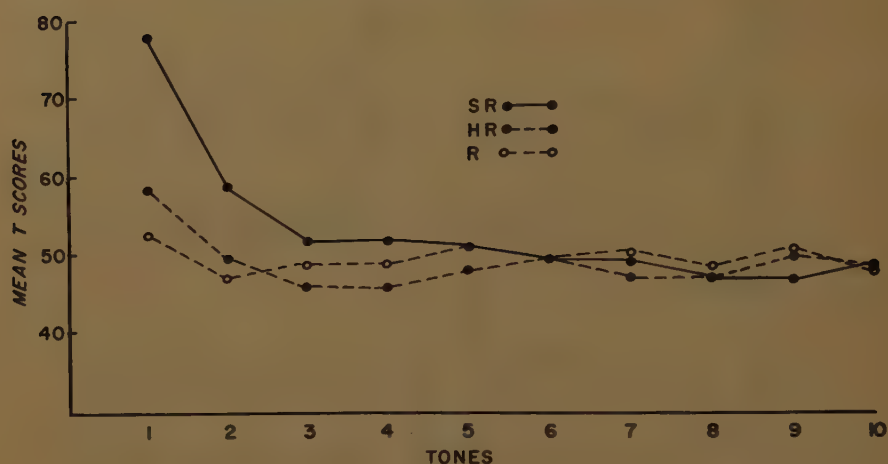


FIGURE 7. Mean T scores for the 40 subjects for each of the first 10 tones in skin resistance (SR), heart rate (HR), and respiration (R).

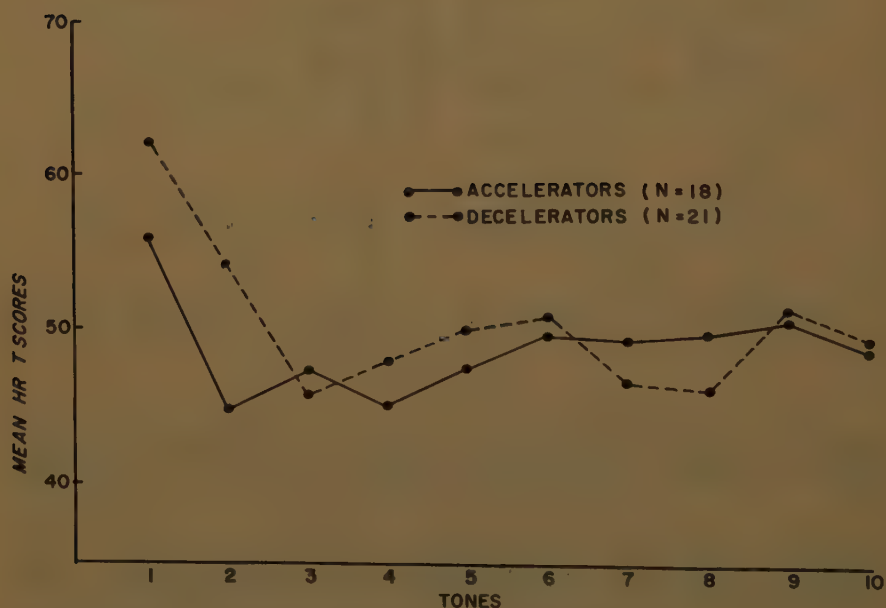


FIGURE 8. Mean T scores in heart rate (HR) for each of the first 10 tones for 2 groups of subjects, those whose stimulus level was greater than the pre-stimulus level on over half the total number of stimuli (accelerators) and those whose stimulus level was less than the prestimulus level on over half the total number of stimuli (decelerators).

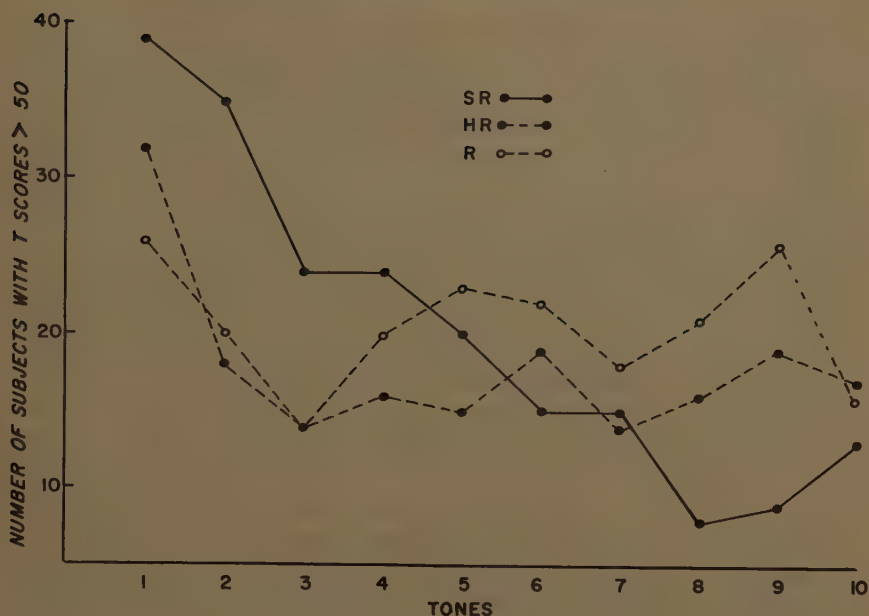


FIGURE 9. Number of subjects having T scores greater than 50 for each of the first 10 tones in skin resistance (SR), heart rate (HR), and respiration (R).

In absolute scores, the SR of all 40 subjects decreased rather appreciably to the first tone, and this was true for most subsequent stimuli, although the change in resistance was considerably less to these latter stimuli. The number of cardiac accelerators on the first 3 tones was 29, 25, and 18, respectively. Cardiac deceleration predominated on each of the next 7 tones. In R, 20 subjects increased their rate of breathing to the first tone, with less than half the subjects accelerating on each of the next 9 tones. There are obvious discrepancies between the T scores and the absolute scores, as might be expected. This evidence again suggests the superiority of the T scores in reflecting adaptation.

A measure designated maximal response time was computed for SR only. This is the time interval between the beginning of an SR response and the point of maximal deflection. FIGURE 10 gives the median maximal response time for the 40 subjects on each of the first 10 tones, and it appears that maximal response time is a good indicator of the adaptation process.

For 6 randomly selected subjects, the PMrs between maximal response times and the intraindividual T scores were obtained. Each coefficient was based on the 18 tones and 11 questions, and they were

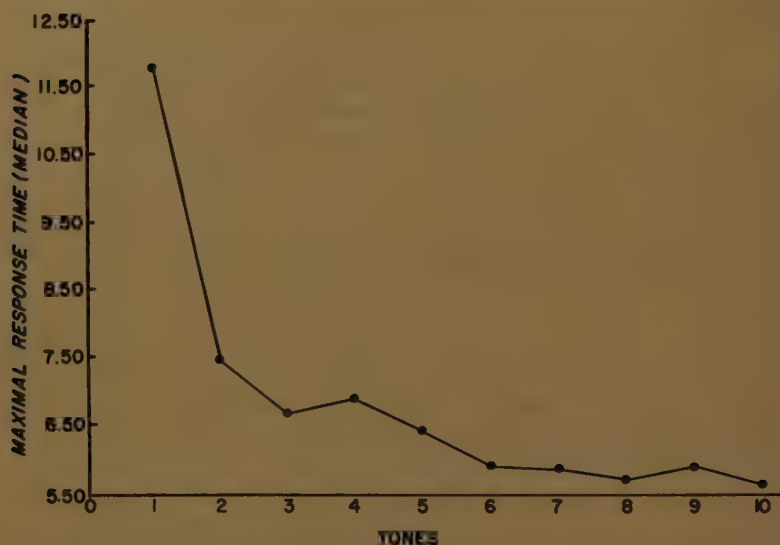


FIGURE 10. Median time interval in seconds from the beginning of a skin resistance response to the point of maximal response for each of the first 10 tones. $N = 40$ for each point on the graph.

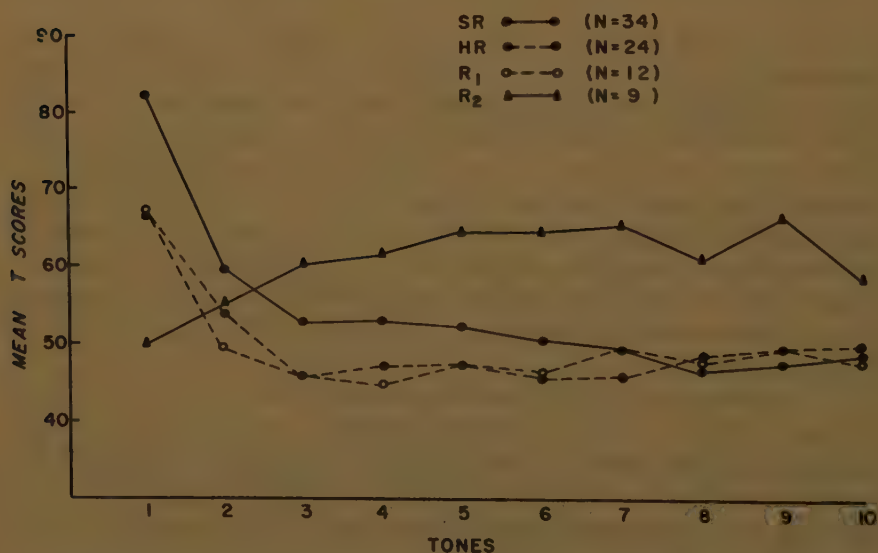


FIGURE 11. Mean T scores for each of the first 10 tones for the 34 skin resistance (SR) adapters; the 24 heart rate (HR) adapters; and 2 groups of respiration adapters, the 12 (R_1) adapters whose breathing accelerated to the first tone only, and the 9 (R_2) adapters whose breathing accelerated during the first few tones.

as follows: 0.65, 0.27, 0.35, 0.06, 0.22, and 0.62. The comparable correlations with absolute scores for the same 6 subjects were: 0.56, 0.27, 0.32, 0.11, 0.26, and 0.64. The 2 sets of coefficients are similar, and it appears that there is a positive association between maximal response time and either T scores or absolute scores.

FIGURE 11 presents adaptation curves for only those subjects whose T-score curves indicated systematic adaptation (34 in SR, 24 in HR, and 21 in R). Cardiac acceleration was the predominant response of the adapters to the early tones. The R results were the least consistent of the 3 systems: 12 of the 21 subjects giving evidence of adaptation in R had a mean T score above 65 to the first tone and then returned to the average predicted level of response, and 9 exhibited a pattern of increasing T scores to the early tones. Adaptation required an average of 3 trials in SR and HR, 1 trial for 1 R group, and 4 trials for the other R group.

FIGURE 12 gives data on trials to adaptation for those subjects who gave evidence of adaptation. The first trial on or exceeding the best-fitting line (see criteria for adaptation above) was termed the adaptation trial. There is very little spread in adaptation, particularly in HR and R, in this homogenous population. FIGURE 13 presents data on systems of adaptation. Only one of the 40 subjects adapted in no system.

Interindividual Analysis

This section is concerned with statistics that assign a subject a position in a group. In intraindividual analysis the regression line and the SE are derived from all the responses of a single subject, but in interindividual analysis these statistics are obtained from the responses of all subjects to a single stimulus. There are as many regression lines as there are subjects in the former and as many regression lines as there are stimuli in the latter. In the intraindividual case, a T score of 60 for a given subject signifies a response that is one SE unit above his average response to all stimuli. The corresponding T score of a subject in the interindividual case indicates a response that is one SE unit above the mean of the group on a particular stimulus.

As mentioned earlier, techniques such as the above are necessary in most autonomic studies, not only because stimulus levels covary with prestimulus levels, but because initial or resting levels are correlated with age.²⁶ In this study, the subjects' ages ranged from 22 to 33, with most of them between 22 and 26. The average HR resting level obtained prior to the introduction of the first stimulus correlated -0.38 ($p < 0.05$) with age. The comparable rank-order coefficient for SR was 0.28

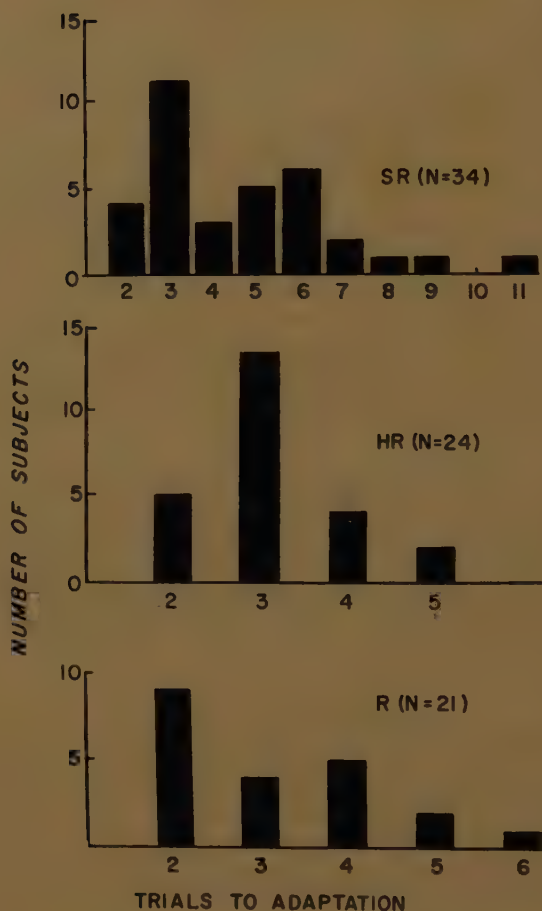


FIGURE 12. Number of subjects adapting in skin resistance (SR), heart rate (HR), and respiration (R) in the indicated number of trials.

($p > 0.05$). These coefficients are substantial considering the homogeneous nature of the population. The correlations for SR and HR between interindividual T scores to the first tone and age were appreciably lower than those between resting levels and age.²⁷

It was reported in the previous section that the intraindividual T scores could not be used without some further transformation as a measure of the relative reactivity of the subjects in different systems. To find out whether the interindividual T scores could serve this purpose, TABLE 4 (which is comparable to TABLE 3) was prepared. The T scores for the low and high scoring subject and the difference between these scores (range) were tabulated for each tone and question. TABLE

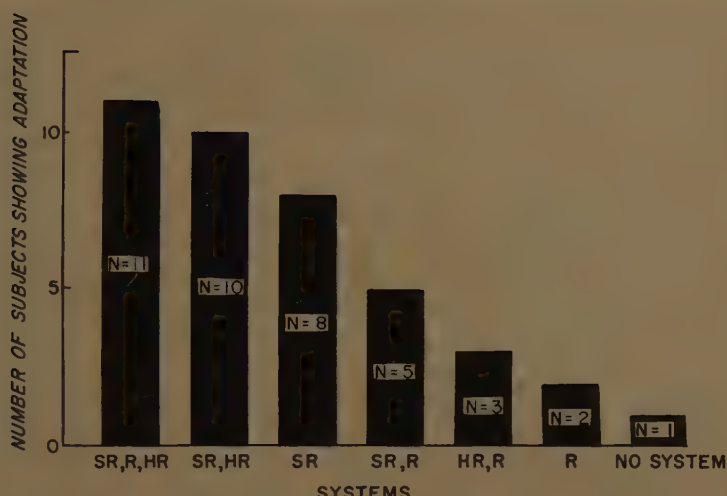


FIGURE 13. Number of subjects giving evidence of adaptation in one or more systems.

4 gives the central tendency and the variability data of these scores for the 3 autonomic systems.

It appears from a consideration of the means and medians and the estimated and obtained semi-interquartile deviations of TABLE 4 that comparisons within systems are legitimate but, as in the case with intraindividual data, comparisons across systems are invalid. The highest mean T score in HR is appreciably lower than the corresponding score in SR and R (note the order of the corresponding low scores). It is not possible, therefore, to determine systems of maximal reactivity without some further transformation of the scores, because the scores in one system would tend to be higher or lower, on the average, than the scores in another. Nor can the scores across systems be directly added to derive a total measure of autonomic functioning, since one item would have a higher or lower weighting than another.

TABLE 5 shows data on the consistency of the subjects in maintaining their group position from one stimulus to the next within various segments of the experiment. Coefficients of concordance and rank order were computed for the indicated blocks of stimuli.⁸ Questions 2, 4, 6, 8, 10, and 11 were emotional in content, and questions Nos. 1, 3, 5, 7, and 9 were nonemotional. While the first question was nonemotional in content, it was considered to have an emotional component resulting from its serial position. It is to be recalled that the emotional questions were alternated with the nonemotional questions, and most of the subjects correctly anticipated the order after the second or third

question. Their state of expectancy was, however, upset by question No. 11. Hence, questions Nos. 1 and 11 were judged to have an element of novelty not present in the other questions and were treated separately.

There are only 4 coefficients of concordance or rank order that are not statistically significant in TABLE 5, and all of these are in HR. The highest degree of agreement is found in SR, the next highest in R, and the lowest in HR. The SR and R coefficients show a tendency to decrease in the successive blocks of stimuli. The statistically significant concordance following adaptation suggests that the subjects tended to maintain relatively distinct levels of functioning even when they were not responding. Low HR and R coefficients on tones Nos. 1 to 6 (inclusive) were expected, since approximately one half of the subjects did not adapt in these 2 systems, and the computations of TABLE 5 are based on all 40 subjects. It is possible that autonomic consistency depends upon the nature of the stimuli, and that more stressful stimuli might produce higher coefficients, particularly in HR and R.²⁷

The relationships among the intraindividual, interindividual, and absolute scores are of special interest. TABLE 6 presents the rank-order correlations within autonomic systems for the 3 types of scores to the first and second tones and the first and eleventh questions. The correlations between the absolute and interindividual scores are sufficiently high, particularly in HR, to suggest that it might not be necessary, in a study such as this, to compute interindividual T scores. It was satisfying to find that the intraindividual scores were significantly correlated with the interindividual and absolute scores, suggesting that the intraindividual scores have an intrinsic validity not generally recognized by psychophysicologists.^{18,19} There may be a spurious element in these correlations, since stimulus levels enter as a common element in all 3 types of scores, but it is believed that this common factor has little effect on the correlations.

Twelve rank-order correlations were computed for the intraindividual and interindividual T scores across systems. The stimuli used for these computations were the first tone and the first question. None of these correlations deviated at a statistically significant level from zero. These findings support a conclusion arrived at earlier in the intraindividual section that a subject's reaction in one autonomic system cannot be predicted from his reaction in another.

A problem of concern to us throughout this research was that of the proper direction of scaling. SR presented no problem because the reactions were unidirectional and, while HR was more of a problem, all but 2 subjects giving evidence of adaptation in HR had a pattern of acceleration to the early tones. Subjects who adapted in R, however,

were approximately equally distributed between individuals responding with acceleration and with deceleration in the rate of breathing. Acceleration in R occurred slightly more frequently than deceleration as a response to significant stimuli, that is, the first tone and the first question.

Despite the foregoing evidence, the possibility existed that a response in HR and R might be better represented in terms of an absolute deviation from the median response than in terms of acceleration. Both the intra- and interindividual T scores to the first tone were rescaled in these terms and then rank ordered. Rank-order coefficients between these intra- and interindividual scores were 0.35 for HR ($p < 0.05$) and 0.31 for R ($r < 0.05$), both correlations being considerably lower than those between T scores scaled unidirectionally. In addition, no statistically significant relations were found between these rescaled scores and the basic psychological variables, but significant relations were found between the unidirectional scores and the psychological variables (see subsequent section). It is concluded that the unidirectional method employed throughout this paper is better than the absolute-deviation method.

FIGURE 14 shows the means of the stimulus and prestimulus levels of all 40 subjects to each tone and question. From the SR graph, it is apparent that the subjects settled down to a rather constant level of responding at about the third tone. A marked adjustment process with trials occurred within both the tone and question periods. The sharp drop in SR between the last tone and the first question is associated with the instructions concerning the questions, and the gradient of adjustment is steeper for the questions than for the tones. The emotional questions produced a greater change in SR on the average than the nonemotional questions.

In HR, it would appear that the typical subject reacted to the first 2 tones only. The complex pattern of HR seen on tones Nos. 11 to 18 (inclusive) may reflect an interaction between the progressive inhibitory effects of the tones and the increasing restlessness of many subjects. The questions substantially increased the HR level, but there is no evidence of differentiation between the emotional and nonemotional questions.

The R means were extremely variable. The sharp peak in the tracing of the stimulus levels resulted from 3 subjects holding their breath on tones Nos. 9, 10, and 11. Since it appears that an acceleration in the rate of breathing is possibly a more meaningful aspect of response than deceleration, it might be desirable, as suggested above, to assign some arbitrary limit to the length of the R cycle. The occasional breath holding found in some subjects would then not have such a distorting

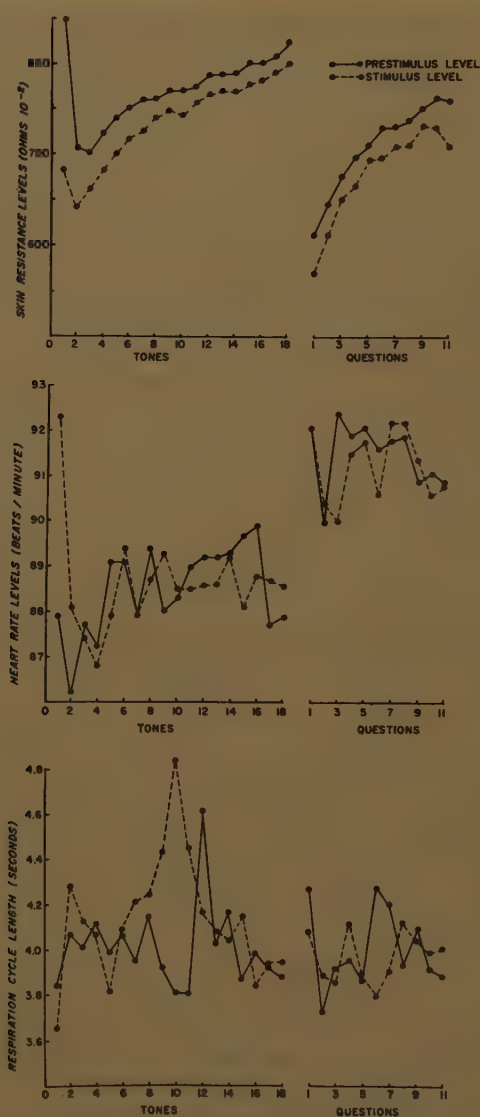


FIGURE 14. Mean stimulus and prestimulus levels for each of the 18 tones and 11 questions for skin resistance (SR), heart rate (HR), and respiration (R). $N = 40$ for each point.

effect on the means and other statistics. The questions did not increase the R rate, and there is no evidence that the R responses to the emotional questions differed from the R responses to the nonemotional questions.

FIGURES 15 and 16 are plots of the interindividual slopes and PMrs. The slopes of SR and HR tend to increase during the early tones.

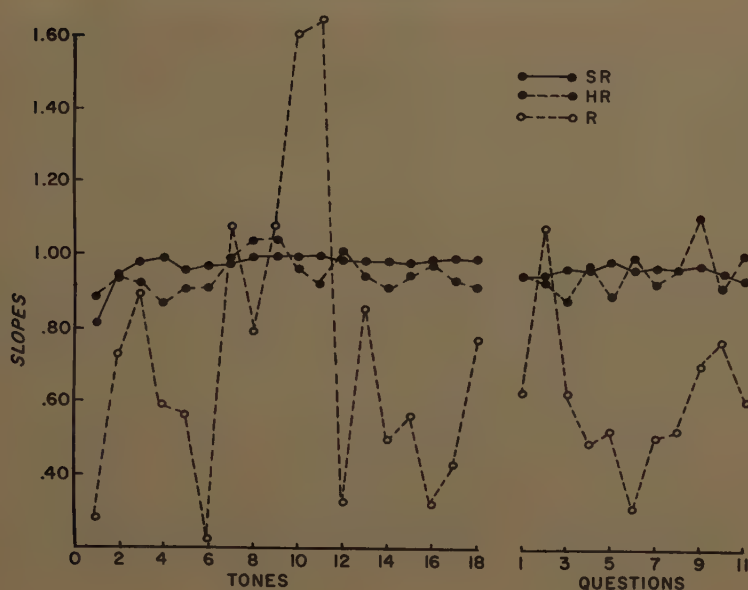


FIGURE 15. Interindividual slopes for each of the 18 tones and 11 questions for skin resistance (SR), heart rate (HR), and respiration (R). $N = 40$ for each slope.

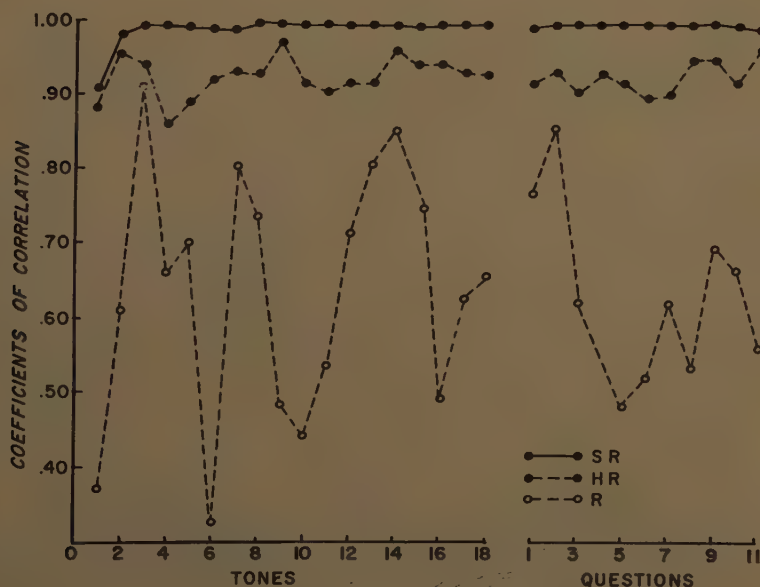


FIGURE 16. Interindividual product-moment coefficients of correlation for each of the 18 tones and 11 questions for skin resistance (SR), heart rate (HR), and respiration (R). $N = 40$ for each correlation.

The most striking feature of these figures is the tremendous variability of the R statistics, which are possibly so variable as to invalidate the method of scaling employed. In general, the pattern of the 2 figures is sufficiently similar to suggest that the regression and correlational models of scaling are about equal from the standpoint of variability (see previous section). The 3 breath holders mentioned above account for the marked peak in the R slopes on tones Nos. 9, 10, and 11. As might be expected, these 3 subjects lowered the corresponding PMrs. The cyclical fluctuations of the PMrs and slopes for R during the tones suggest that extrachance factors are involved in the variation of the R data, and it may be that these fluctuations are related in some complex way to periodic breath holding.

FIGURE 17 gives the interindividual SEs and standard deviations of the stimulus and prestimulus levels in SR. The comparable HR and R data will not be presented; it is necessary to mention only that these data were far more variable, and that the first tone produced a larger SE than the subsequent stimuli. By comparing the SR means (FIGURE 14) and standard deviations, it may be seen that during the question period the variation tended to increase with increasing levels of SR. In the case of the tones, the SR mean levels and the standard deviations

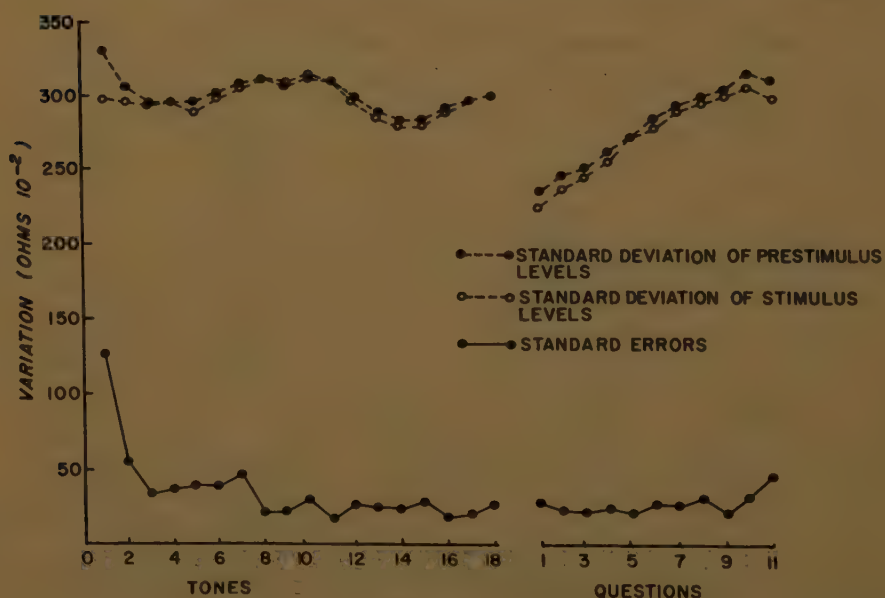


FIGURE 17. Interindividual standard errors and interindividual standard deviations for stimulus and prestimulus levels for each of the 18 tones and 11 questions for skin resistance. $N = 40$ for each point.

were generally higher than for the questions, but the deviations did not increase as the mean level of SR increased. These comparisons suggest that variation is less at low levels of SR, increases as the mean resistance level increases during intermediate levels, and at high levels approaches an asymptote even though SR continues to climb.

The interindividual SEs of SR decreased markedly on the first 3 tones, remained approximately level for the next 4 tones, and then decreased again. Most of the adaptation variation was eliminated by the third tone, but a component of this variation persisted until the eighth tone. Even though the SR levels were increasing on tones Nos. 8 to 18 (inclusive) and during the questions, the SEs remained relatively constant. An estimation of the extent to which the regression of stimulus on prestimulus has reduced the variability may be gained by comparing the standard deviations with the SEs. This reduction was also found in HR and, to a much lesser extent, in R.

To secure more specific evidence of the relationship of the variability of the data to prestimulus levels, samples of SR stimulus levels within successive prestimulus subranges of 10,000 ohms were obtained. The standard deviations of the stimulus levels in each prestimulus subrange were computed; these are shown in FIGURE 18. In

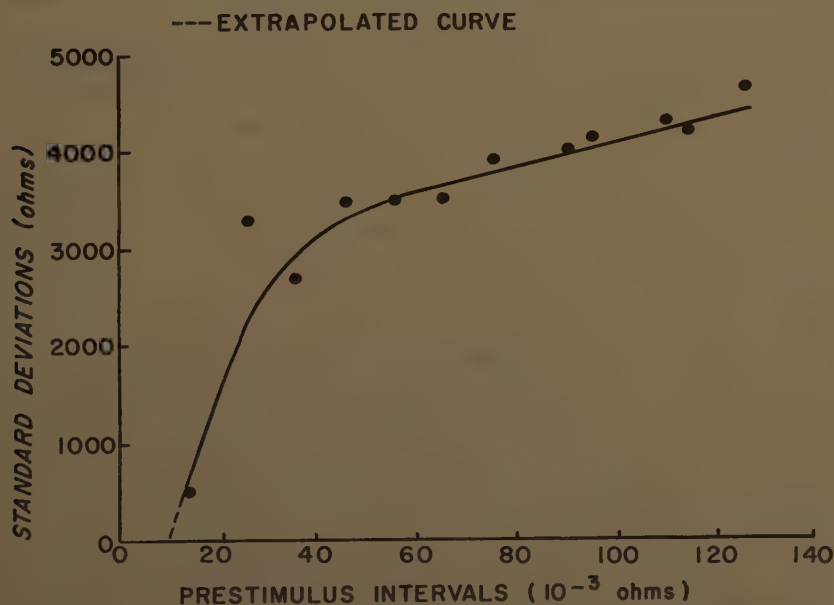


FIGURE 18. Standard deviations of stimulus levels of skin resistance as a function of prestimulus levels. Each point on the abscissa is the midpoint of a range of 10,000 ohms. The dotted portion of the line is an extrapolation to zero variability (see text).

preparing these data, only the last 12 tones were used; thus the major part of the adaptation process was eliminated. The standard deviation of the subrange 10,000 to 20,000 ohms is based on 12 stimulus levels, and the standard deviation of the highest subrange is based on 15 stimulus levels. All other standard deviations are based on 23 stimulus levels. Furthermore, the standard deviation of the lowest subrange is based on the data of a single subject (the only one who had SR values this low), but the other standard deviations incorporate data from at least 3 subjects. The dotted part of the curve is an extrapolation to zero variability. It is to be noted that the standard deviations vary only moderately over the usual functioning range of most subjects, which is 30,000 to 120,000 ohms. The SEs and coefficients of nondetermination were also computed for each prestimulus subrange, and these statistics increased as did the standard deviations with increasing prestimulus levels. Similar analyses for HR and R indicated that the range of stimulus levels in HR varied only slightly over the prestimulus subranges, while the range of stimulus levels in R increased as the length of the prestimulus cycles increased.

We reported above, in discussing FIGURE 17, that the interindividual SEs remained relatively constant during the latter tones and during the questions even when the average levels of SR were increasing. These data seem to contradict the findings reported above. There are several possible reasons for such a discrepancy, but most pertinent is the fact that the SEs of FIGURE 17 are confounded by the varying prestimulus levels of the different subjects. There is a further possibility that the generalized adjustment occurring with trials tends to attenuate the variation. In FIGURE 18 the adjustment is controlled, since the samples of stimulus levels for different prestimulus subranges were drawn independently of trials.

Psychophysiological Interrelationships

Background data on the students participating in this experiment were collected from a variety of sources. The Taylor Manifest Anxiety Scale⁴¹ was administered to the students during the early part of their junior year in medical school. The scores on the Medical College Admission Test (MCAT), normally taken before the student enrolls in medical school, were supplied to us by the Office of the Provost.⁵ From the student health clinic it was learned that all except two students were in good physical health (these students had minor cardiac disorders) and that one student had been placed in the diagnostic category "anxiety reaction." Additional psychological data on each subject were obtained from an interview that immediately followed the autonomic

test. The following nine variables were isolated from each subject's interview protocol.

(1) The number of words and feelings used in dictating an account of the experiment, the first phase of the terminal interview. These accounts were also evaluated by a psychiatrist (WGR) to gain some idea of personality structure.

(2) Time disorientation as judged by error in estimating the duration of the tones, the interval between tones, and the length of the experiment.

(3) Count disorientation as judged by error in estimating the number of tones and the number of questions.

(4) Self-rated anxiety during the various phases of the experiment (at the time the recording electrodes were attached, during the rest period, the first two tones, the middle tones, and at other times). A five-point scale was employed in these ratings.

(5) Self-evaluation of the most bothersome or stressful aspects of the experiment (monotony of the tones, novelty, feeling of being tested, isolation, actions of the experimenters, restraint, uncertainty as to the purpose of the experiment, and extraneous noises).

(6) The number and types of physical symptoms reported (such as drowsiness, numbness, cardiac acceleration, breathing difficulty, and sweating).

(7) Negativism, as judged from the answer and comments to the question, "Would you like to go through this procedure again?"

(8) The average number of hours of study per day during the freshman and sophomore years.

(9) Attitudes concerning success or lack of success in medical school.

Inspection revealed that most of the variables derived from the interview were not significantly related to the physiological variables. Some few of the interview variables bore a significant relation to one or more physiological variables, but only average self-rated anxiety appeared to be significantly related to enough physiological variables to warrant further study. The self-rated anxiety score of a student was the average of his anxiety ratings for eight successive phases of the experiment, from the time the recording electrodes were attached until after the last question was asked (see number 4, above).

On the basis of the findings of others and theoretical considerations of our own, 3 additional psychological variables were selected for statistical analysis: Taylor scores corrected for defensiveness (see below), scores on the K scale, and average scores on the 4 sections of the MCAT. The Taylor scale purports to be a measure of generalized drive or emotionality,^{41,42} and the test includes 50 items rated by clinicians as indicating manifest anxiety. These items were derived

from the Minnesota Multiphasic Personality Inventory³² and, while they seem naïve on inspection (for example, "I do not tire quickly," "I work under a great deal of strain"), were shown to be meaningful in a number of studies.⁴² In addition, the test proper contains 175 buffer items, including most of the items on the L, K, and F scales of the Minnesota test, as well as some items measuring personality rigidity. Of the buffer items we considered only those that make up the K scale (the Taylor scale contains 28 of the 30 K-scale items). The K scale, among other things, seems to reflect a certain type of defensiveness: the tendency of a person to deny abnormality in himself and others.^{32,50} The MCAT, which consists of verbal, quantitative, modern society, and science sections, purports to be a measure of general achievement and ability.⁵ The product-moment intercorrelations of the basic psychological variables here studied are given in TABLE 7.

TABLE 7

PRODUCT MOMENT INTERCORRELATIONS OF THE
BASIC PSYCHOLOGICAL VARIABLES

	Taylor scale	Modified Taylor	Self-rated anxiety	K scale
Taylor	—	—	—	—
Modified Taylor	0.81*	—	—	—
Self-rated anxiety	0.14	0.09	—	—
K scale	-0.58*	0.00	-0.11	—
MCAT	0.00	0.14	-0.22	0.20

* $p < 0.01$

It has been reported previously, in agreement with the findings of this study, that the K scale is negatively correlated with the Taylor scale;^{32,49} individuals low in defensiveness tend to have higher Taylor scores on the average than do individuals high in defensiveness. To take account of this relationship, modified Taylor scores were derived by a statistical procedure similar to the one employed in scaling autonomic responses. Using the PMr as a slope measure and the coefficient of nondetermination as a measure of the variation around the slope, each Taylor score was assigned a T-score equivalent. Wolff,⁴⁹ who was apparently the first to correct Taylor scores for the K-scale correlation by the regression technique, theorizes that measured anxiety (the raw Taylor score) is a resultant of basic anxiety modified by defensiveness. He terms measured anxiety corrected for defensiveness nondefended anxiety.

After the psychological variables to be studied were reduced to the 4 most promising, the number of physiological variables was also reduced to 44 that appeared to sample well 2 aspects of response: response to significant stimuli and response to the total experimental situation (see below). These restrictions had the effect of circumscribing the number of psychophysiological relationships to be considered from a population of several thousand to about 175.

Some of the psychological variables that were eliminated bore a statistically significant ($p < 0.05$) relation to the more efficient objective measures: time disorientation correlated 0.42 with the raw Taylor scores, combined time and count disorientation scores correlated 0.41 with the raw Taylor scores (time and count disorientation intercorrelated 0.55); count disorientation correlated 0.40 with the number of words, 0.44 with the number of feelings, and 0.47 with self-rated anxiety; and the number of feelings correlated 0.39 with self-rated anxiety (rank-order correlations). Correlations were obtained for only those psychological variables that appeared from inspection to bear a significant relationship to each other. These correlations are of considerable interest in themselves, apart from any physiological considerations, and the statistically significant results indicate that it might be profitable to develop more efficient measures of some of them.

The physiological variables, as mentioned above, were grouped on an *a priori* basis into two classes: those indicating reactions to the total experimental situation (situational reactivity) and those indicating reactions to the specific stimuli (stimulus reactivity). The following outline lists the variables comprising each physiological class and gives, in addition, the direction of change postulated as being associated with high scores on the basic psychological variables. High physiological reactivity has been defined in terms of a decrease in SR and an acceleration in HR and rate of breathing (see above).

A: Variables Indicating Situational Reactivity

(1) High average levels of functioning during the rest period and high average prestimulus levels during the tone and question periods. It is to be recalled that the autonomic test consisted of 3 phases: a rest, a tone, and a question period. Each subject had 9 average values, 1 each for SR, HR, and R during the 3 phases of the autonomic test. This analysis employed the absolute values and not the T scores.

(2) Poor adjustment from the rest period to the question period. The average levels were rank-ordered, and poor adjustment was defined in terms of a relative increase in the level of autonomic functioning. Each subject had 3 adjustment ratings, 1 each for SR, HR, and R.

(3) High maximal reactivity T scores within autonomic systems. For each subject there was isolated within a single autonomic system the stimulus producing the reaction of greatest magnitude. The regression of these maximal reactions on average resting levels gave T scores comparable to the interindividual T scores to any stimulus. Each subject had 3 maximal reactivity scores, one for each autonomic system.

(4) High total maximal reactivity scores. These scores were derived by adding the separate maximal scores for SR, HR, and R. Each subject had one total maximal score.

(5) Large spreads and SEs. These statistics were derived from the total number of responses elicited from a single subject (see under *Intraindividual Analysis*, above). Each subject had 3 spreads and 3 SEs, 1 for each of the 3 systems.

(6) Low-consistency scores. These scores reflect changes in the rank-order position (based on interindividual T scores) of subjects on the successive stimuli within certain blocks of the experiment. We are here concerned with only 2 blocks of stimuli: the first 6 tones and the nonemotional questions (Nos. 3, 5, 7, and 9). Each subject had 6 consistency scores: 3 for each autonomic variable in the 2 blocks of stimuli.

(7) A low number of regular SR responses. A regular response is defined as one that has a latency of less than 2 sec., a magnitude of at least 800 ohms, and that recovered at least 800 ohms during a period of 10 sec. following the initiation of the reaction. The number of regular responses was tabulated for each subject.

B: Variables Indicating Stimulus Reactivity

(1) High intraindividual T scores to the first tone and the first question. These scores reflect the relative magnitude of a subject's response to the first tone or question as contrasted with his average level of response to all stimuli. Each subject had 6 scores: 2 for each stimulus in the 3 systems.

(2) High interindividual T scores to the first tone and the first question. These scores reflect the relative magnitude of a subject's response to the first tone or question as compared with the average reaction of all subjects on these stimuli. Each subject had 6 scores: 2 for each stimulus in the 3 systems.

(3) High total intraindividual T scores to the first tone. These scores were obtained by adding the intraindividual T scores across systems. These scores were normalized prior to adding, since it was found that direct comparisons across systems are invalid. Each subject had one total intraindividual T score.

(4) High total interindividual T scores to the first tone. These scores were derived by adding the interindividual T scores across systems. As in the case of the intraindividual scores, normalization prior to adding was necessary, and each subject had one such total score.

(5) A long maximal response time in SR to the first tone. Maximal response time refers to the duration (in seconds) between the onset of an SR response and the point of maximal deflection. Each subject had one maximal response time.

It is important to note, before considering the results, the fact that the psychological analysis is exploratory in nature. We expected the subjects who were high in anxiety (both in the Taylor scores and in self-rated anxiety) to be more reactive physiologically, but there seemed to be no good basis for deducing the physiological pattern associated with either the K scores or the average scores on the MCAT. Thus, the statistically significant relations reported in this section must be cross-validated. It is further probable that socioeconomic factors such as age, physical fitness, and motivation play a role in the results here reported, and other studies in this laboratory are investigating certain of these background factors.

For the major statistical analyses of this section, the subjects were divided into 2 groups on each physiological variable, those above and those below the median. For a given physiological variable the psychological data for the 2 groups of subjects were then entered. The means and variances were computed for each group, and differences were tested for significance employing the *t* test for means and the *F* test for variances.⁸ The level of statistical significance was arbitrarily placed at $p < 0.10$, because any difference this large was judged to be worthy of exploration in subsequent studies.

TABLES 8 and 9 present data on the pattern of the means and variances. For purposes of convenience, these tables are arranged to indicate the number of groups having the higher autonomic levels that also had the higher mean scores or variances on the psychological variables. For example, the first entry in TABLE 8 indicates that low levels of autonomic functioning are associated with high modified Taylor scores. There were 9 pairs of modified Taylor means for autonomic levels, 1 pair in each system for resting, tone, and question levels. The subjects with low levels of autonomic activation had the higher modified Taylor means in 7 of the 9 pairs; the 2 exceptions shown in the table are the R levels to tones and questions. Thus, the subjects with higher average levels of HR and lower average levels of SR tended to have lower modified Taylor scores. The number of possible means for each cell may be obtained by dividing the possible

TABLE 8

NUMBER OF PSYCHOLOGICAL MEANS HIGHER IN THE HIGH AUTONOMIC GROUPS THAN IN THE LOW AUTONOMIC GROUPS

Physiological variables	Number of concordant means*				Totals (rows)	Possible totals
	Modified Taylor	Self-rated anxiety	K scale	MCAT		
Situational reactivity						
High levels	2	7 (1)	6 (1)	6 (1)	21	36
Poor adjustment	2 (1)	1	3	2	8	12
High maximal scores	1 (1)	2	3 (1)	3 (1)	9	12
High total maximal scores	1 (1)	1	1	1	4	4
Large spreads and SEs	6 (3)	5	4 (1)	2	17	24
Low consistency	5 (1)	1	5 (1)	5 (2)	16	24
Low in regular SR responses	1	0	0	1	2	4
Subtotals (columns)	18	17	22	20	77	116
Possible subtotals	29	29	29	29	116	
Stimulus reactivity						
High intra. scores	5	5 (2)	2	4 (1)	16	24
High inter. scores	2 (1)	6 (2)	4	4 (1)	16	24
High total intra. scores	0	1 (1)	1	1	3	4
High total inter. scores	1	1 (1)	0	1	3	4
Long SR response time	1 (1)	0	1	1	3	4
Subtotals (columns)	9	13	8	11	41	60
Possible subtotals	15	15	15	15	60	
Grand totals (columns)	27	30	30	31	118	176
Possible grand totals	44	44	44	44	176	

*The numbers in parentheses are the number of means in each cell significantly higher by statistical test in the high autonomic groups than in the low groups at the 10 per cent level of confidence or less.

totals in the last column by 4. The comparable cell in TABLE 9 indicates that 4 of the 9 groups having the higher autonomic levels had the higher variances in modified Taylor scores (about chance expectancy).

The number enclosed in the brackets is the number of means or variances significantly higher in the high autonomic groups than in the low autonomic groups at the 10 per cent level of confidence or less. There were 8 statistically significant differences that ran in a direction opposite to that of TABLE 8, and all but 2 were in SR. In

TABLE 9

NUMBER OF PSYCHOLOGICAL VARIANCES HIGHER IN THE HIGH AUTONOMIC GROUPS THAN IN THE LOW AUTONOMIC GROUPS

Physiological variables	Number of concordant means ^a				Totals (rows)	Possible totals
	Modified Taylor	Self-rated anxiety	K scale	MCAT		
Situational reactivity						
High levels	4	4	3	2	13	36
Poor adjustment	1	1	1 (1)	2	5	12
High maximal scores	2	0	1	1	4	12
High total maximal scores	1	0	1	0	2	4
Large spreads and SEs	3	3	4	0	10	24
Low consistency	2	4	3 (1)	2 (1)	11	24
Low in regular SR responses	0	1	1	0	2	4
Subtotals (columns)	13	13	14	7	47	116
Possible subtotals	29	29	29	29	116	
Stimulus reactivity						
High intra. scores	4	4	3 (1)	0	11	24
High inter. scores	2	4	2	1	9	24
High total intra. scores	0	0	0	0	0	4
High total inter. scores	1	0	0	0	1	4
Long SR response time	1	0	1	0	2	4
Subtotals (columns)	8	8	6	1	23	60
Possible subtotals	15	15	15	15	60	
Grand totals (columns)	21	21	20	8	70	176
Possible grand totals	44	44	44	44	176	

^aThe numbers in parentheses are the number of variances in each cell significantly higher by statistical test in the high autonomic groups than in the low groups at the 10 per cent level of confidence or less.

the 176 pairs of means, there were 34 significant differences (the 26 given in the table and the 8 others mentioned above). Of the 34 significant differences, 13 were significant at the 10 per cent level of confidence, 15 were significant at the 5 per cent level, and 6 were significant at the 1 per cent level. It might be assumed that 18 (10 per cent of 176) of these were significant by chance. However, in the corresponding 176 F tests, only 8 significant differences were obtained: the 4 shown in TABLE 9 and 4 that ran in a direction opposite to that of this table.

The total scores are of special interest since they are a composite measure of activity in the 3 systems, and it might be postulated that these scores would be a good measure of anxiety. Two of the 6 significant differences at the 1 per cent level of confidence were in total scores: subjects with higher total maximal reactivity scores had higher modified Taylor scores, and subjects with higher total intraindividual T scores had higher self-rated anxiety scores than subjects in the low autonomic groups. In addition, subjects with higher total interindividual T scores tended to be higher in self-rated anxiety than subjects in the low group ($p < 0.05$). The other statistically significant means and variances will be listed later.

It may be seen from inspecting the grand totals of TABLE 8 that the more reactive subjects from a physiological standpoint tended to have higher modified Taylor scores (in 27 of 44 pairs of means, $p = 0.09$), higher self-rated anxiety ($p = 0.01$), higher K scores ($p = 0.01$), and higher scores on the MCAT ($p < 0.01$). The probabilities presented in the preceding sentence and those that follow are based on the binomial expansion unless otherwise indicated. The significant MCAT results depended upon HR and R, because subjects reactive in SR (low levels, large responses to stimuli, and others) tended to have lower average scores on the MCAT (in 10 of the 15 pairs of means). The corresponding grand totals in TABLE 9 indicate that the more reactive physiological groups were significantly less variable with respect to MCAT scores ($p < 0.01$). The variances for the other psychological variables are approximately equal to chance expectancy. It should be remembered that the 4 psychological variables had negligible inter-correlations (TABLE 7).

Turning to the 2 types of reactivity: subjects who were high, compared to those who were low, in situational reactivity tended to be higher on all the psychological variables but, in particular, they had higher K scores ($p < 0.01$) and higher scores on the MCAT ($p = 0.03$). With respect to stimulus reactivity, statistically significant differences were found on 2 variables: subjects who were high on this type of reaction tended to be higher in self-rated anxiety ($p < 0.01$) and to have higher scores on the MCAT ($p = 0.06$). TABLE 9 indicates that the more reactive physiological groups were more homogeneous with respect to scores on the MCAT on both the situational variables (in 7 of 29 pairs of variances, $p = 0.01$) and the stimulus variables ($p < 0.001$).

Some idea of the efficiency of the different physiological variables in making a combined psychological discrimination may be gained by inspecting the rows of TABLE 8. The combined psychological variables for each row exceed the mean chance expectancy in every case except for the number of regular SR responses. The mean chance expectancy

may be computed by dividing the entries in the column for possible totals by 2. Several of the differences are significant by binomial expansion: high maximal scores ($p = 0.07$), high total maximal scores ($p = 0.06$), large spreads and SEs ($p = 0.03$), low consistency ($p = 0.08$), high intraindividual T scores ($p = 0.08$), and high interindividual T scores ($p = 0.08$). There were 116 pairs of means for situational reactivity, and the high autonomic groups had 77 of the possible 116 high psychological means ($p < 0.001$). For stimulus reactivity, there were 60 pairs of means, and the high autonomic groups had 41 of the possible 60 high psychological means ($p < 0.01$). Thus, subjects who were high on the above physiological variables tended to have higher scores on all the psychological measures.

A similar row-by-row analysis of the variances indicates that only levels ($p = 0.07$) and high total intraindividual T scores ($p = 0.07$) are statistically significant. However, the high physiological groups were comprised in general of individuals who were more homogeneous in their psychological performance than the low groups. Of the 116 pairs of variances for situational reactivity, the high autonomic groups had only 47 of the higher psychological variances ($p = 0.05$). The comparable stimulus reactivity variables were also significant ($p = 0.09$). In the total 176 pairs of variances in TABLE 9, the high physiological groups had 70 (mean chance expectancy equals 88) of the higher psychological variances ($p < 0.01$).

The foregoing conclusions were derived from a pattern analysis of all the means, with no consideration of whether the individual means are statistically significant. We think it of interest to contrast the interpretations arrived at by a pattern analysis of all the means with the interpretations arrived at by a consideration of only the statistically significant means. The above findings will be summarized first with certain extensions pertaining to the systems of reactivity, and this will be followed by a detailed listing of the means significant by the *t* test at the 10 per cent level of confidence or less (2-tailed test).

For the purpose of clarity, the ensuing presentation will be oriented in terms of the physiological reactions of subjects who are high on the psychological variables, even though the statistical analysis was done on the opposite basis. The analysis to this point has been oriented in terms of the psychological scores of subjects who are high or low on a variety of physiological variables. There is no reason to believe, however, that the major conclusions depend upon the direction of analysis.*

*About 60 contingency tables were prepared as a check on this procedure, and it was found that the direction of the variables was identical in all cases to the directions of the means derived from the method described above. The data that were statistically significant by contingency analysis were, in general, also significant by the *t* test, although the latter produced a slightly greater number of significant differences.

The pattern analysis of all the means indicated that the subjects with high modified Taylor scores, in contrast to those with low scores, failed to react at a statistically significant level either to the stimulus variables (the first tone and the first question) or to the situational variables. The high Taylor subjects had relatively lower levels of autonomic functioning in SR and HR, lower maximal reactivity scores in SR and R, lower interindividual T scores in SR and HR, and lower total intraindividual T scores; however, they had higher total maximal scores and relatively larger spreads and SEs in all 3 systems studied, fewer regular SR responses, higher intraindividual T scores in SR and R, higher total interindividual T scores, and a longer maximal response time in SR to the first tone. In addition, they made a poorer adjustment from the rest to the question period in HR and R, and they exhibited a greater variation in group position from trial to trial in SR and HR. Over-all, they were most reactive in R, next in HR, and least in SR (TABLE 8).

Turning to the means that were significant by t test, subjects with high modified Taylor scores in contrast to subjects with low scores had the following nine characteristics: (1) higher resting levels of SR in ohms ($p < 0.10$); (2) higher intraindividual SEs in SR ($p < 0.10$); (3) greater variation in HR as judged by the intraindividual spreads ($p < 0.05$) and the SEs ($p < 0.01$); (4) poorer adjustment in HR from the rest to the question period ($p < 0.01$); (5) higher maximal reactivity scores in HR ($p < 0.10$); (6) longer maximal response times in SR to the first tone ($p < 0.10$); (7) higher maximal reactivity total scores ($p < 0.01$); (8) a tendency to be less consistent in maintaining their group position between stimuli as reflected by their interindividual T scores to the tones in HR ($p < 0.05$); and (9) higher interindividual T scores in R to the first tone ($p < 0.10$).

It would appear from the statistically significant means that the high Taylor subjects were more reactive in situational than in stimulus variables. Of the 3 systems studied, HR yielded the greatest number of significant differences, and there was a greater number of concordant significant differences at the 10 per cent confidence level or less with the Taylor test than the other psychological variables. These conclusions are dependent upon the number of variables, and it is necessary to keep in mind that there was a greater number of situational than stimulus variables and a slightly greater number of variables in SR than in HR or R.

Subjects high in self-rated anxiety during the various phases of the experiment, in contrast to the less apprehensive subjects, reacted at a statistically significant level to the stimulus variables ($p < 0.01$), but not at a statistically significant level to the situational variables.

The apprehensive subjects made a relatively good adjustment in SR and HR from the rest to the question period, were consistent in maintaining their group position between stimuli in SR and R, had a higher number of regular responses in SR, and had a shorter maximal response time in SR to the first tone. Turning to the variables on which they were reactive, they had relatively higher levels of functioning except for the resting level in R and the question level in SR, higher maximal scores in SR and HR, higher total maximal scores, larger spreads and SEs except for the HR spread, higher intraindividual T scores except for the T scores in HR to the first question, higher interindividual T scores in all systems, and higher total inter- and intraindividual T scores. Their pattern of reactivity was in some ways just the opposite of the high Taylor subjects (TABLE 8). Irrespective of the type of physiological variable, they were approximately equally reactive in all 3 systems.

In contrast to the less apprehensive subjects, they: (1) had higher resting levels of HR ($p < 0.05$); (2) made good adjustments in SR from the rest to the question period ($p < 0.10$); (3) were more consistent in maintaining their group position in R, as indicated by their interindividual T scores to the first 6 tones ($p < 0.05$); (4) were more reactive to the major stimuli in SR, as reflected by the intraindividual T scores to the first tone ($p < 0.05$) and the interindividual T scores to the first question ($p < 0.05$); (5) were more reactive to the major stimuli in R, as reflected by the intraindividual T scores to the first question ($p < 0.10$) and by the interindividual T scores to the first tone ($p < 0.05$); (6) had a greater number of regular SR responses ($p < 0.05$); and (7) had higher total autonomic scores, both intraindividual ($p < 0.01$) and interindividual ($p < 0.05$) to the first tone.

The pattern of the means significant by *t* test in agreement with the pattern of all the means suggests that the more apprehensive subjects as compared with the opposite group of subjects were more reactive to stimulus than situational variables, and that they were equally reactive in all 3 systems. These interpretations are subject to the same limitations that were mentioned above in summarizing the Taylor results.

Subjects with high K scores reacted to the situational variables ($p = 0.01$), but they were relatively unreactive to the stimulus variables. They had relatively higher levels in SR and HR, higher maximal reactivity scores in all 3 systems, higher total maximal reactivity scores, a greater variation in intraindividual spreads and SEs except for the spread in R and the SE in SR, higher interindividual T scores in HR and R, higher total intraindividual T scores, and a longer response time in SR to the first tone, and they made a poorer adjustment from the rest to the question period in all 3 systems. However, they had a relatively

lower number of regular responses in SR and lower intraindividual T scores aside from the R scores to the first tone and the HR scores to the first question. In general, they were most reactive in HR and moderately reactive in SR and R.

Turning to the means significant by t test, subjects with high defensiveness (high K scores) in contrast to subjects low in defensiveness (1) had lower average levels of SR to the tones ($p < 0.05$); (2) had higher intraindividual spreads in HR ($p < 0.05$); (3) were less consistent in maintaining their HR position in the group as judged by their interindividual T scores to the nonemotional questions ($p < 0.01$); and (4) had higher maximal reactivity scores in SR ($p < 0.10$).

Only 4 significant differences in K scores were found, 2 each in SR and HR. These significant differences occurred on variables that have been classified as situational variables. Thus, the results of the 2 types of pattern analysis are in agreement.

Subjects who had high scores on the MCAT were reactive to both situational variables ($p = 0.03$) and to the major stimuli ($p = 0.06$). These subjects had relatively higher levels in HR and R, higher maximal reactivity scores in all 3 systems studied, higher total maximal scores, fewer regular SR responses, higher intraindividual T scores in HR and R, higher interindividual T scores in HR and R, higher total intra- and interindividual T scores, and a longer maximal response time in SR to the first tone. In addition, they made a poorer adjustment from the rest to the question period in SR and HR, and they were less consistent in maintaining their group position to SR and R stimuli. There was but one variable on which they did not give evidence of greater reactivity than the lower scoring subjects; this was the intraindividual spreads and SEs, but even here they exhibited a greater spread and SE in HR. Across all physiological variables they were reactive in HR and R and relatively unreactive in SR.

In contrast to the subjects with low scores, the subjects with high scores on the MCAT (1) had higher average resting ($p < 0.10$) and higher average question ($p < 0.05$) levels of SR; (2) had higher average question levels of HR ($p < 0.05$); (3) were less variable in R as judged by their intraindividual spreads ($p < 0.10$); (4) were less consistent in maintaining their group position in R, as indicated by their interindividual T scores to the first 6 tones ($p < 0.10$); (5) were less consistent in maintaining their group position in SR to the questions ($p < 0.05$); (6) had higher maximal reactivity scores in HR ($p < 0.10$); (7) were more reactive to the first tone in HR, as judged by the intraindividual T scores ($p < 0.10$) and by the interindividual T scores in SR to the first question ($p < 0.05$); and (8) had lower interindividual T scores in SR to the first question ($p < 0.01$).

In agreement with the pattern of all the means, the pattern of the significant means suggests that the subjects who had higher scores on the MCAT were more reactive to situational variables than stimulus variables, although they were relatively reactive on both classes of variables.

As mentioned above, there were several significant differences in the variances, and these are reported below. It was found, in general, that the high physiological groups were comprised of subjects who were less variable or more homogeneous in their psychological performance than the low physiological groups.

Subjects in the high physiological groups, in contrast to those in the low group were: (1) less variable in self-rated anxiety as reflected by the total interindividual T scores ($p < 0.05$); (2) less variable in K scores as determined by resting levels of HR ($p < 0.10$), total intra-individual autonomic scores ($p < 0.05$), and by intraindividual T scores in HR to the first tone ($p < 0.10$); (3) more variable in K scores, as judged by HR adjustment from the rest period to the questions ($p < 0.05$), by intraindividual T scores in R to the first question ($p < 0.05$), and by their consistency in maintaining a group position on the first 6 tones in HR ($p < 0.10$); and (4) more variable in average scores on the MCAT, as determined by their consistency in maintaining a group position on the nonemotional questions in SR ($p < 0.05$).

Several additional analyses of the physiological variables were carried out that are not incorporated in TABLES 8 and 9. These variables were not included in the tables because there was no rational way of deciding whether they should be classified under situational or stimulus reactivity. It was found that subjects who had high intraindividual slopes tended, in general, to have higher scores on all the psychological measures, modified Taylor scores in particular; none of these differences were significant by the *t* test. It was found further that subjects who had high intraindividual PMrs in contrast to subjects with low PMrs had higher K scores in all 3 systems ($p < 0.10$ by the *t* test for SR and for R). Also, the high PMr group in R were relatively less variable in their K scores ($p < 0.10$ by the *F* test).

Several other aspects of adaptation were studied, and it was found that subjects who adapted in R exhibited somewhat lower modified Taylor scores ($p < 0.10$ by the *t* test) than those who did not adapt and that subjects who adapted in HR had higher average self-rated anxiety scores ($p < 0.05$ by the *t* test) than those who did not adapt. The SR results were not statistically significant, but this would be expected from the fact that there were only 6 subjects who failed to give evidence of adaptation in this system.

The subjects were also placed in high and low physiological groups

on the basis of the number of trials required for adaptation (FIGURE 12), and the rapid and slow adapters did not differ on the basic psychological variables. There was very little variation in the number of trials required for adaptation in this relatively homogeneous population.

In addition, we attempted to find out whether the different adaptation groups varied in psychological performance (FIGURE 13). By the Chi-square test, the groups differed with respect to modified Taylor scores ($p < 0.10$) and self-rated anxiety ($p < 0.01$). The statistical significance on the Taylor test was due to 3 groups: subjects who adapted both in SR and R had relatively lower modified Taylor scores, but the subjects who adapted in both SR and HR or in SR only had relatively higher modified Taylor scores. The self-rated anxiety difference was due to 3 groups: SR and HR adapters had relatively higher self-rated anxiety scores, but the subjects who adapted in SR only and in both SR and R had relatively lower self-rated anxiety scores.

DISCUSSION

This paper has two major themes: the problem of autonomic quantification and the study of various autonomic reactions to novel stimuli. It is perhaps a truism to say that any success achieved in the latter endeavor is to a large extent dependent upon the success in the former. Contrary to the procedure in most scientific papers, the RESULTS section above has already been elaborated by discussion, although it is restricted in the main to information needed to comprehend the results. In this section the task becomes that of attempting to deal with the two principal themes of this paper in a somewhat more integrated fashion.

The Problem of Autonomic Quantification

The basic quantification technique employed in this paper was an adaptation of a method recommended by Lacey.²⁶ It consisted, in brief, of finding the best-fitting line (in the least-squares sense) between stimulus and prestimulus levels of autonomic functioning. The stimulus levels were then scaled in terms of their deviation (the standard error distance) from this line. This procedure is commonly employed in psychological studies.^{8,16}

There were two basic types of autonomic analyses in this study: intraindividual and interindividual. In intraindividual analysis, the magnitude of a subject's response to a given stimulus depends upon the position of that response relative to his total population of responses. For any one autonomic system, there are as many distributions of responses as there are subjects. In interindividual analysis the magnitude of a subject's response to a given stimulus depends upon the

position of that response relative to the responses of all other subjects to that same stimulus. For any one system, there are as many distributions as there are stimuli, and each stimulus is treated as if it were a separate "stressor."

The term response, as used in the foregoing description, should be qualified. In this paper, response has been used interchangeably with stimulus level, and it should be clear that a given stimulus level may or may not be a response in any real sense. In regression analysis the numerical value attached to a stimulus level depends upon the deviation of that stimulus level from the best-fitting line; for example, a T score of 50 implies the average expected stimulus level of functioning, a T score of 20 a stimulus level that is 3 standard deviations below the mean expected stimulus level.

Whether the mean expected stimulus level or any other stimulus level is to be regarded as a response depends upon some *a priori* or *post hoc* specification. This problem remains unsolved in the present paper because there seemed to be no way of arriving at a thoroughly satisfactory definition of what constitutes the absence of response.

There may be some question about the intraindividual analysis of the present study stemming from the fact that the basic statistics employed in the scaling procedure were derived from a combined analysis of two different types of stimuli, tones, and questions. This appeared to be a justifiable procedure, however, since the autonomic plots for the two types of stimuli were generally linear even though in some cases there were dramatic shifts in the level of functioning. This combined analysis had the advantage of yielding a larger population of "responses" with which to work in establishing the basic scaling statistics. The fact that the results for simple and complex stimuli could be combined is a significant finding in itself, and suggests that stress experiments of a widely varying nature might be plotted on the same regression line.

Lacey²⁶ recommends that the intraindividual distributions be normalized. He normalizes the stimulus and prestimulus distributions by the McCall technique prior to regression analysis. In this method of normalization the scores in a distribution are assigned percentile ranks, and these ranks are converted to normalized scores by finding the standard deviation values that correspond to the percentile ranks in a normal distribution.^{8,16} Whatever the shape of the original distribution, the final distribution is normal. While Lacey admits that this is an irrational procedure, he has found that the McCall scores are highly correlated with the standard scores of distributions that are normalized by square root or logarithmic transformations.

It is our belief that an investigator should not attempt to normalize

autonomic data prior to regression analysis; that is, one should extract as much information as possible before distorting the original data by normalization. It is a common maxim in the field of measurement not to normalize unless there is good reason to believe that the obtained scores misrepresent the true distribution of scores, and this does not seem to be the case with our data.¹⁶ If normalization is necessary for certain purposes, such as deriving total autonomic scores, this should be done after the stimulus levels are first scaled by the technique of this study rather than prior to regression analysis. It is important to emphasize the fact that the T scores employed in the present research do not alter the shape of the original distribution. Our procedure merely shifts the mean to 50 and the standard deviation to 10. If the original distributions are skewed, the transformed distributions will be skewed and in precisely the same manner as the original distributions.

Various results of our study suggest that the regression model here used is not a completely adequate technique for autonomic scaling in a serial type of experimentation: (1) in the intraindividual analysis, the best-fitting mathematical line for many subjects deviated from the manifest trend of their data; (2) the standard scores in both intraindividual and interindividual analysis could not be used to compare responses in different autonomic systems, although they could be used to compare reactions within a single system; (3) the SEs, slopes, and PMrs varied with the serial position of stimuli in the three autonomic systems studied; and (4) the SEs increased with increasing prestimulus levels in SR and R, but this was not true of HR.

The foregoing considerations suggest that the scaling techniques employed in this paper could be improved, but it is not believed that the aforementioned findings affect the validity of the results. There were many reasons to be pleased with the results achieved by the present methods, particularly in SR and HR. Considering the relatively low number of observations from which the slopes and SEs were computed, it might even be argued that the over-all results were fairly consistent. It is true that the R results were highly variable, but this probably depends upon the inherent unreliability of the system and not upon the technique of scaling. We have submitted evidence to indicate that comparisons within systems are valid (see TABLES 3 and 4 and DISCUSSION) and we have normalized the T scores when making comparisons across systems. While the SE of SR and R increases as a function of prestimulus level, the magnitude of increase is not appreciable in the usual functioning range of most subjects. In addition, it appears that the regression line requires only a minor rotation in most subjects to produce a satisfactory degree of concordance between the

mathematical model and the experimental data (see FIGURE 3). It is concluded that the results presented in this paper are reliable.

Autonomic Reactions to Novel Signals

It was indicated in a preceding section (*Reactions to Novel Stimuli*) that past studies of reactions to novel stimuli encompass both the startle and orienting reactions. While the present work was designed primarily as an orienting study, the sudden and unexpected auditory stimulus was sufficiently loud to evoke a mild startle reflex in about one third of the subjects. This appeared only on the first tone and was absent on the remaining stimuli.

No attempt was made in this study to separate the subjects who startled from those who oriented, and this is perhaps an interesting problem for future consideration. In brief, we were looking for a one-session test that might be employed in subsequent studies to differentiate "normals" from psychiatric and neurological patients. It seemed best, therefore, to employ a stimulus of sufficient intensity to elicit a fairly consistent reaction on at least the first presentation.

The startle reaction in our subjects appeared primarily as an eye-blinking response; the other components of the pattern as described by Landis and Hunt²⁸ were not observed. However, to be absolutely certain that these other components were absent, it would have been necessary to take motion pictures of the reaction. As a group, the subjects more frequently exhibited orienting behavior: a slow shifting of the eyes upward, a tendency to sit up somewhat in the chair, an ill-defined puzzled look, and heightened attentiveness.

It would appear that background conditions apart from stimulus intensity are of importance in determining whether a subject will startle or orient. The subjects who were drowsing at the time of the first tone were more likely to startle than the subjects who were awake. This suggests, as Lazrus and Deese²⁹ have pointed out, that the degree of arousal produced by a stimulus depends upon the initial level of arousal, the type of relationship found for autonomic reactions in this and other studies. Background factors seem to be of particular importance in animals. The dog, for example, often gives no evidence of a startle reflex to even relatively loud sounds when he is in a familiar environment. When the dog is in a strange environment and obviously "keyed up," either weak or strong stimuli produce a maximal immediate response. Fleck,¹⁰ as mentioned earlier, states that the OR of dogs is more or less independent of stimulus intensity.

Perhaps the most important findings of the present research, aside from those bearing on the problem of scaling, were those relating to autonomic adaptation. We found, as have others,^{4,28,31,33,46} that

adaptation to novel stimuli occurs very rapidly (see INTRODUCTION), and that adaptation in one autonomic system can not be predicted from adaptation in another.²⁷ Of the 40 subjects studied, there were 34 who gave evidence of adaptation in SR, 24 in HR, and 21 in R. Only one subject failed to give evidence of adaptation in at least one system. The number of trials required for adaptation varied from 2 to 11 in SR, 2 to 5 in HR, and 2 to 6 in R (FIGURES 12 and 13). It has been previously noted that autonomic adaptation does not occur so rapidly in the dog.^{7,36}

Davis *et al.*⁴ have reported that the latency of the SR response shows no tendency to change in a systematic manner with trials. In the present study, SR was recorded at a paper speed of 0.1 inch per second, and this is obviously too slow to allow for a rigorous analysis of latency. It appeared from inspection, however, that the latency of the SR response is about 1.5 sec. and varies little with trials, either within or between subjects. We did find that the latency of the peak response (the time interval between stimulus onset and the point of maximal deflection) gave good evidence of adaptation (FIGURE 10).

Of the three systems we studied, SR gave the best evidence of adaptation. While fewer subjects gave evidence of adaptation in HR, we believe that the HR results are reliable and representative of the type of reactions novel stimuli elicit. The results for R were sufficiently variable, however, to cast doubt on any systematic adaptation in this system (FIGURES 7, 8, 9, 11, and 12). It may be impossible to derive any really satisfactory quantitative measure of R for humans.⁵ Qualitative measures may be more satisfactory. Our means of recording R left much to be desired, and the pneumograph should perhaps be replaced by a device that measures the direct exchange of air.

An attempt was made in this study to explore certain relationships between psychological and physiological variables. Four psychological measures were employed: the K scale of the Minnesota Multiphasic Personality Inventory; the Taylor Manifest Anxiety Scale also derived from the Minnesota Multiphasic Personality Inventory; self-rated anxiety for various phases of the experiment; and scores on the MCAT.^{5,32,41,42} It was found that the more reactive subjects on a battery of physiological measures were in general more reactive psychologically. Subjects who denied abnormality in themselves and others (as reflected by higher scores on the K scale) were more reactive on a number of physiological variables indicating responsiveness to the total experimental situation, which suggests that they pay a physiological price for their greater psychological defensiveness. Substantial positive relationships were also found between self-rated anxiety and autonomic reactivity (principally in those variables indicating reactivity to significant stimuli). These

are of interest since, of the four psychological measures used, only self-rated anxiety had a component reflecting response to the immediate experimental conditions. The most surprising finding of all was that subjects who had high scores on the MCAT tended to be more reactive physiologically than subjects with low scores. The MCAT purports to measure both ability and achievement, and it is likely that high scores on the MCAT are also indicative of a greater need to achieve. From this standpoint, the MCAT results might be expected, since there may be a positive relationship between motivation and autonomic reactivity.

With the possible exception of self-rated anxiety, our psychological tests measured general psychological functioning. Investigation of the relationships between certain defense mechanisms (such as rationalization, compensation, and projection) and physiological reactivity are needed. Even more-specific studies are possible. It would be interesting, for example, to require subjects to rate the intensity of auditory stimuli in terms of some reference stimulus, studying the relationship between their subjective ratings and autonomic responses.

It is also probable that certain parameters of the conditioning process might be predicted from orienting parameters. Hull^{22,23} and his followers³⁷ have postulated that reaction tendency (the tendency to respond) is a multiplicative function of drive (summation of all extant need states of the organism both primary and secondary) and habit strength (what has been learned in a given situation). In most conditioning studies, drive is defined in terms of the number of hours of deprivation, and it is possible that certain OR components would afford an independent measure of the drive or "emotional" level of a subject. This suggests a type of experimentation, for example, in which novel stimuli are interposed in some aperiodic manner between conditional stimuli. The relationships among central nervous system variables and autonomic and motor functions^{3,12,28,30,31,34,46} deserve more attention. Davis⁴ has studied muscle action potentials to strong stimuli, and Landis and Hunt²⁸ have taken motion pictures of such reactions, but there is no comparable work for the OR. While the day-to-day adaptation process has been given some attention in studies on animals,³⁶ such studies have not been done on humans. It should be clear that the present study has hardly scratched the surface of the intriguing possibilities in this area.

SUMMARY

This study had three principal aims: (1) the exploration of various techniques of autonomic quantification; (2) the study of physiological reactions to novel stimuli; and (3) the study of relationships between physiological reactions and psychological variables.

Forty male junior medical students, 22 to 33 years of age, served as subjects. The experiment ("test") consisted of three phases: (1) a rest period of 15 min.; (2) a tone period of 18 min.; and (3) a question period of 11 min. The subjects received 18 tones (each lasting 5 sec., 800 cps, about 60 db, and given at 1-min. intervals) and were asked 11 alternating emotional and nonemotional questions (requiring 2 to 4 sec. to read and given at 1-min. intervals). The subjects were instructed to think about the questions, but not to answer them aloud. Continuous recordings were made of skin resistance, heart rate, and respiration, with excellent instrumentation, except possibly for respiration. The autonomic responses were scaled by a modification of the regression method proposed by Lacey.²⁶

Evidence was presented to indicate that:

(1) Of the systems studied, skin resistance was the easiest to evaluate and the most consistent.

(2) Autonomic responses to serially presented stimuli rapidly diminish to a relatively constant level in normal humans.

(3) Subjects are more reactive in skin resistance than in heart rate or respiratory rate, both in terms of the magnitude and the frequency of response.

(4) The magnitude of an autonomic response is dependent upon the initial level of functioning; in general, the higher the initial level the smaller the response (Wilder's rule).

(5) The relationship between stimulus levels of autonomic functioning and initial levels is linear, and this was true even for subjects who exhibited a dramatic shift in initial levels to the questions.

(6) Many of the subjects exhibited a marked and systematic "adjustment" in skin resistance, which appeared in their records most often as an increasing level of resistance during the tone and question periods. The instructions concerning the questions frequently interrupted the adjustment. Adjustment occurred less often in heart rate and respiration than in skin resistance.

(7) The psychogalvanic reaction in normals is more stimulus-bound than the heart rate or respiration reactions (heart rate and respiration appear to be more dependent upon intraorganismic factors than does skin resistance).

(8) An individual's reaction in one autonomic system can not be predicted from his reaction in another.

(9) Subjects tend to maintain their group position in the three systems studied from one stimulus to the next.

(10) The magnitude of reaction as judged by intraindividual data is correlated with the magnitude of reaction as judged by interindividual data.

(11) Subjects who are apprehensive in most life situations (as judged by scores on the Taylor Manifest Anxiety Scale) tend to operate at higher autonomic levels on a class of variables indicating reactivity to the total experimental situation (such as resting levels and consistency in maintaining group position from one stimulus to the next) than less-apprehensive subjects. The over-all difference between subjects high in anxiety and low in anxiety was not significant by statistical test.

(12) Subjects who deny abnormality in themselves and others (as judged by higher scores on the K scale) tend to operate at higher autonomic levels on a class of physiological variables indicating reactivity to the total situation (such as resting levels and consistency in maintaining group position from one stimulus to the next) than the opposite group of subjects.

(13) Subjects who are apprehensive during the actual course of the experiment (high average self-rated anxiety for various phases of the experiment) tend to operate at significantly higher autonomic levels on a class of variables indicating reactivity to the stimuli such as magnitude of response to the first tone and the first question and maximal response time in skin resistance than subjects who are less apprehensive.

(14) Subjects who are more intellectually proficient and have a higher achievement motivation (as adjudged by MCAT scores) tend to operate at higher autonomic levels on physiological variables indicating reactivity to both the total situation and to stimuli than subjects with low scores.

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